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Santa Ana River

Design Memorandum No. 1

PHASE II GDM ON THE SANTA ANA RIVER MAINSTEM including Santiago Creek

VOLUME 4
MILL CREEK LEVEE

August 1988

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This volume accompanies the Main Report and Supplemental Environmental Impact Statement for the Phase II General Design Memorandum for the Santa Ana River Mainstem including Santiago Creek and contains the general design information for the Mill Creek Levee.

Design Memorandum No. 1

Volume 4

Santa Ana River Mainstem

including Santiago Creek, California

Phase II General Design Memorandum

MILL CREEK LEVEE

SYLLABUS

This volume accompanies the Main Report and Supplemental Environmental Impact Statement for the Phase II General Design Memorandum for the Santa Ana River Mainstem including Santiago Creek and contains the general design for the Mill Creek Levee. The project economic data is presented in Volume 9, "Economics and Public Comment and Response." The recommended flood control plan for the Mill Creek levee consists of raising a portion of the existing levee from stations 70+00 to 88+70, extending the toe protection from stations 70+00 to 129+33.33 and from stations 130+72 to 196+25.37, and constructing a floodwall along the top of the levee from stations 70+00 to 130+20 and from stations 130+72 to 196+25.37. Esthetic treatment will consist of groupings of native trees and large shrubs planted along the landward side of the embankment. Total first cost for this element of the Santa Ana River Mainstem project is estimated at $5,109,000.

PHASE II GDM LISTING OF VOLUMES

PERTINENT DATA

Mill Creek Levee

Item	Unit
Drainage Area	52 mi^2
Peak discharge, SPF	33,000 ft^3/s
Levee:	
Length	13,600 feet
Height (above streambed)	10 feet (Maximum)
Slopes:	
Streamward side (existing)	1V on 2.25H
New (Sta 70+00.00 to Sta 88+70.00)	1V on 2H
Landward side	1V on 2H
Top width	18 feet
Recommended floodwall:	
Length	12,573 feet
Height	7' 6" (Maximum)
Toe extension on streamward side	12' 6" (Maximum)
Toe slope	1V on 2H

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I. INTRODUCTION

Authorization

1-01 Authorization for construction of the Mill Creek Levee is contained in the Water Resources Development Act of 1986, 99th Congress 2nd Session, Public Law 99-662. The project for flood control is contained in the Report of the Chief of Engineers for the Santa Ana River Mainstem, including Santiago Creek, California, dated January 15, 1982, except that, in lieu of the Mentone Dam feature of the project, the Secretary is authorized to plan, design, and construct a flood control storage dam on the upper Santa Ana River. The full authorization language is presented in the Main Report.

Scope and Purpose of Report

1-02 This volume of the Phase II General Design Memorandum (GDM) describes the existing physical conditions in the project area and provides definite design for the Mill Creek Levee. This Phase II GDM provides the basis for project features, establishing the project rights-of-way and easements, updating the project costs, assessing the environmental effects, and preparing contract plans and specifications.

Local Cooperation

1-03 This division of federal and non-federal responsibilities for local cooperation are outlined in the Main Report.

II. PROJECT PLAN

2-01 Mill Creek (pl. 1) is a tributary to the Santa Ana River and is located in San Bernardino County, California. The confluence of Mill Creek and the Santa Ana River is approximately 5 miles northeast of the City of Redlands. The City of Mentone lies 2 miles south of the confluence. Mill Creek generally flows in an east to west direction and originates in the high mountain peaks about 18 miles east of the Santa Ana River confluence. Maximum streambed gradients along the project exceed 200 feet per mile.

Description of the Project Area

2-02 The area tributary to the Mill Creek Levee comprises about 52 square miles (mi^2), bounded on the north by the San Bernardino Mountains, on the east by the San Gorgonio Mountains, on the south by the Crafton Hills and Yucaipa Ridge, and on the west by the Santa Ana River. Elevations in the drainage area range from about 11,500 feet National Geodetic Vertical Datum of 1929 (NGVD) at San Gorgonio Peak to about 1,700 feet NGVD at the confluence of Mill Creek and the Santa Ana River. The average slope of the streambed in the project reach is approximately 4 percent. Upstream from the project reach, the average gradient of the main channel of Mill Creek is about 565 feet per mile. The physiographic features of the Mill Creek watershed make it one of the most severe sediment producers in the area. Mill Creek is confined by an existing Federal flood control levee on the south side; however, the floodway is relatively wide.

2-03 Urban developments occur primarily in the south overbank areas of the Mill Creek alluvial plain. The Cities of Redlands and Mentone lie on the historic alluvial fan of Mill Creek. There are some agricultural lands in the north overbank area of Mill Creek and a river run hydropower plant, the Mill Creek Powerplant Number 1, owned by the Southern California Edison Company.

Existing Flood Control Facilities

2-04 Levees and floodwalls have been constructed at various times by Federal and local interests along the south bank of Mill Creek. The original Federal flood control project was a unit of the Santa Ana River Basin project, which was authorized by the 1950 Flood Control Act. Construction of the existing Mill Creek Levee was completed in 1960. The improvements integrated two stone masonry floodwalls constructed immediately after heavy flooding in 1938 by local interests with Works Progress Administration (WPA) funds. The Mill Creek Levee was designed for a maximum flood capacity of 33,000 cubic feet per second (ft^3/s), providing Standard Project Flood (SPF) protection to the Cities of Mentone and Redlands, and to the surrounding urban areas.

2-05 The existing Mill Creek Levee consists of three levee segments. The upstream levee joins a 1,297-foot-long stone masonry floodwall. The floodwall extends from station 216+86.93 to station 203+89.59 and is about 24 feet high with a base width of 10 feet and a top width of 4 feet. At the base of the floodwall there were 6-foot-high, 5-foot-wide and 20-foot-long groins, at 100-foot spacings. These groins have been destroyed by flooding and sediment movement.

2-06 The upstream levee is 520 feet long and extends from station 208+50.38 to station 203+30.20 where it joins a second masonry wall. The levee height varies from 5 to 9 feet above the streambed with a crest width of 18 feet. The side slopes are 1 vertical on 2.25 horizontal on the river side and 1 vertical on 2 horizontal on the landward side. The river side of the levee is protected with a grouted cobblestone layer varying in thickness from 18 inches at the toe to 12 inches at the top. The revetment extends 12 feet below the lowest point in the streambed along this reach.

2-07 The second masonary floodwall is 705 feet long and extends from station 203+30.20 to station 196+25.37. The wall was constructed at the same time and to the same dimensions as the upstream masonry floodwall. At the downstream end, the masonry floodwall joins a middle levee.

2-08 The middle levee is 6,553 feet long and extends from station 196+25.37 to station 130+72.00, ending at the crossing of Garnet Street (pl. 2). The levee height varies from 5 to 9 feet above the streambed. The top width, side slopes, and revetment are the same as the upstream levee. The height from the top of levee to toe of revetment varies from 14 to 22 feet.

2-09 The downstream levee begins at Garnet Street as a tie back and then extends downstream 6,575 feet from station 135+75 to station 70+00 (pl. 2). The top width and side slopes are the same as the upstream levees. Between stations 135+75 and 88+70, the revetment is also identical to that on the other two levees and the height from top of levee to toe of revetment varies from 11 to 20 feet. The levee height in this reach varies from 4 to 11 feet above the streambed. From station 88+70 to station 70+00 the revetment consists of a 24-inch layer

of dumped stone extending from the top of the levee to the streambed. The toe of the revetment extends 2 feet below grade. The height of the levee in this reach varies from 2 to 4 feet above the streambed.

2-10 Since construction of the existing Mill Creek Levee, floods smaller than the design capacity of the project have overtopped the levee and caused damage. Additional features, such as gabion deflection baffles, mid-stream "pushed-up" dikes, and low flow pilot channels, have been constructed under Federal emergency programs to rehabilitate and improve the project. These features are further discussed in the Hydraulic Design section of this report.

2-11 The Mill Creek Levee was constructed in 1960 for $653,720. A cumulative total of $1,087,000 has been spent under Federal emergency programs to rehabilitate the project after flood damage.

The Flood Problem

2-12 The flood problem results from overtopping of the levee during flows of less than design capacity, which transport large amounts of sediment while following a meandering flow pattern. This sediment has deposited on the levee slopes and created a ramp, allowing flows to escape. Scour in other reaches has undermined the revetment in the past. For a complete description of the flooding phenomena and hydraulic design see section IV.

The Authorized Plan

2-13 The 1980 Santa Ana River Phase I GDM plan consisted of raising the existing levee and constructing an additional 1.2 miles of levee to convey flows to the proposed Mentone Reservoir. The authorized plan also included a groin field along the levee extension to protect the levee and divert flows away from the Mentone Dam spillway. The estimated cost of construction for the improvements was $15,095,000 (October 1979 price levels).

The Plan Recommended in this Report

2-14 The recommended flood control plan for Mill Creek Levee is similar in concept to the authorized plan, except that the channel will not be extended an additional 1.2 miles downstream; the existing levee toe protection will be deepened, and a concrete floodwall will be constructed on top of the levee berm in lieu of raising the entire levee (pls. 3 through 13). Replacement of Mentone Dam with Seven Oaks Dam removed the need to extend the Mill Creek Levee to protect the Mentone Dam spillway from sediment deposition. Details of the recommended improvement to the Mill Creek Levee are described in the following paragraphs.

RAISED LEVEE

2-15 The levee will be raised 4 feet at station 70+00 tapering down to 0 feet at station 88+70. The side slope will have an average height of 18 feet and will be protected with 18 inches of grouted stone. The existing ungrouted revetment will remain in place beneath the new side slope.

TOE PROTECTION

2-16 The recommended toe protection for the Mill Creek Levee will be constructed of grouted stone revetment with a slope of 1 vertical on 2 horizontal. It consists of the following:

(1) From station 70+00 to station 88+70, grouted stone slope protection will be constructed as part of the levee raising. The new toe depth will vary from 6.5 to 9 feet deeper than the existing ungrouted toe.

(2) From station 88+70 to station 129+33.33, the toe of the existing grouted revetment will be deepened. The new toe depth will vary from 2 to 8 feet below the existing toe and will consist of 18-inch-thick grouted stone.

(3) From station 130+72 to station 196+25.37, the toe of the existing grouted revetment will be extended. The new toe depth will vary from 8 to 12.5 feet below the existing toe and will consist of 18-inch-thick grouted stone.

FLOODWALL

2-17 The recommended floodwall for the Mill Creek Levee will be constructed along the existing top of the levee from station 88+70 to station 130+20 and from station 130+72 to station 196+25.37 and along the top of the raised levee between station 70+00 and station 88+70. The height of the wall will vary from 5 feet 11 inches to 7 feet 6 inches. The wall will be designed as an inverted T-wall. The footing will be 6-foot in length and will rest on top of the levee. The thickness of the stem and the footing will be 8 inches and 10 inches respectively. A cutoff wall, 3 feet deep and 10 inches thick, will be provided at the end of the footing (river side). See plate 14 for a typical floodwall section. The wall will be provided with two 3-foot wide by 6-foot high access gates. The gates will be designed as floodgates and will provide access to the existing catwalks for diversion facilities at station 118+10 and station 157+00. Also, ladder rungs will be provided at 300-foot intervals to assist viewing the river side over the floodwall from the access road (pl. 14).

ESTHETIC TREATMENT

2-18 Groupings of native trees and large shrubs (table II-1) will be planted on the landward side of the embankment, along the levee reach upstream of Garnet Street and the one-third distance of levee downstream from Garnet Street, to reduce the unnatural horizontal line created by the long floodwall. The plantings will be established by a single mainline drip irrigation system. The esthetic treatment plan is shown on plates 15 through 17.

2-19 No coloring of the floodwall will be necessary since the existing predominant grayish-white coloration of the riverbed is similar to concrete. No esthetic treatment will be necessary on the river side of the levee since this side is generally visible only from great distances. The following plant species will be considered for planting within the rights-of-way:

Table II-1. Mill Creek Levee Plant List.

Trees:		
	Black Willow	Salix gooddingii
	Red Willow	Salix laevigata
	Arroyo Willow	Salix lasiolepis
	Golden Willow	Salix lasiandra
	Fremont Cottonwood	Populus fremontii
	California Sycamore	Platanus racemosa
Shrubs:		
	Common Buckwheat	Eriogonum fasciculatum
	Brittle Bush	Encelia farinosa
	Chamise	Adenostoma fasciculatum
	White Sage	Salvia apiana
	California Sagebrush	Artemesia californica
	Mexican Elderberry	Sambucus mexicana
	Mule Fat	Baccharis glutinosa
	Sugar Bush	Rhus ovata
	Hairy Yerba Buena	Eriodictyon trichocalyx

Consideration of Other Alternatives

2-19 The following alternatives were also considered during this Phase II GDM study:

a. Raising the levee with additional compacted fill and constructing groin fields and gabion deflection baffles at strategic locations.

b. Raising the levee with additional compacted fill and relocating the Garnet Street Bridge to improve the flow direction and capacity through the bridge.

c. Constructing a parallel levee along the river side slope of the existing levee and using the existing levee as a back-up in the event of overtopping.

Each of the above alternatives also involved increasing the depth of the levee toe protection approximately 10 to 15 feet.

2-20 As the flow capacity of the existing levee was adequate, raising the existing levee with additional compacted fill was considered for controlling the sediment ramping effect (described in the hydraulic design section of this report) during events below the SPF. Increasing the height of the sloped levee face was not efficient because sediment ramps build higher on the slope surface. The cost of groin fields and gabion deflection baffles was extremely high and functionally questionable. The parallel levee concept could be implemented within the existing rights-of-way, but the costs exceeded the recommended plan.

2-21 Relocation of Garnet Bridge was considered as a possible solution to improve flow conditions and prevent flows from impinging directly on the levee face downstream from the bridge. The cost of constructing a new bridge over 400 feet long was estimated at about $2,000,000 and the effectiveness to eliminate the flow impingement was questionable.

2-22 The historic performance of the levee and the WPA masonry walls indicates that the vertical-faced masonry wall has effectively deflected debris and is less susceptible to build-up of sediment ramps than the sloped-face levee. Therefore, floodwalls were evaluated and subsequently selected as the recommended plan. The floodwalls were found to be the least costly alternative evaluated.

III. HYDROLOGY

Introduction

3-01 Development of the hydrology for the original Mill Creek Levee was presented in the report titled "Hydrology, Santa Ana River and Tributaries, California," which was submitted as enclosure 2 to the District Engineer's report dated 1 November 1946 and titled "Report of Survey of Santa Ana River and Tributaries, California, for Flood Control." The results of the hydrologic engineering studies were presented in "Design Memorandum No. 1, Hydrology for Mill Creek Levees," dated June 1958.

3-02 Hydrologic engineering evaluations conducted during the Phase II studies for the Mill Creek Levee and the entire Santa Ana River Mainstem Project are presented in Volume 7, Hydrology, of this Phase II GDM. This section presents a brief description of Mill Creek and presents the design discharge for the existing levee.

General

3-03 The Mill Creek watershed (pl. 20), in the San Bernardino Mountains, has a drainage area of 52 mi^2. Elevations range from 11,502 feet at San Gorgonio Peak to 1,700 feet at the confluence with the Santa Ana River. The principal channel of Mill Creek flows westerly and has an average gradient of 565 ft/mile for the area upstream from the levee. The maximum gradients of the smaller tributaries exceed 1,900 ft/mile. The watershed is presently in a natural undeveloped state and is expected to remain in that state during the life of the project. The existing Mill Creek levee and some channel stabilization improvements are the only existing flood control structures on Mill Creek.

3-04 Mean seasonal precipitation for the project drainage area ranges from about 45 inches in the headwaters to about 20 inches at the site of the levee and averages about 32 inches. Nearly all precipitation occurs

during the months of December through March. Rainless periods of several months during the summer season are common. Most precipitation in the drainage area results from general winter storms that are associated with extratropical cyclones of north Pacific origin. Major storms consisting of one or more cyclonic disturbances, occasionally last 4 days or more, and result in intense precipitation over large areas. Thunderstorms that may result in intense precipitation during short periods over small areas occur occasionally either in association with general storms or independently. Summer thunderstorms and tropical cyclones are infrequent. Snow is common in winter at the higher elevations, but records indicate that peak flows resulting from rainfall are usually not affected appreciably by snowmelt.

3-05 Runoff concentrates quickly from the steep slopes in the mountains and hydrographic records show that the streamflow increases rapidly in response to effective rainfall. High-intensity rainfall, in combination with the effects of steep gradients and possible denudation by fire, can result in highly intense, debris-laden floods. Except for a few days in some years, Mill Creek streamflow is perennial upstream from the canyon mouth, but intermittent in the levee reach and usually dry in the summer season.

Design Flood Peak Discharge

3-06 The design flood peak discharge of 33,000 ft^3/s, used for the entire levee reach, is the standard project flood (SPF) peak discharge. The SPF peak discharge was derived from the SPF hydrograph (fig. 1), which was developed by critically centering a general winter standard project storm over the Mill Creek watershed upstream of its confluence with the Santa Ana River.

IV. HYDRAULIC DESIGN

Introduction

4-01 Hydraulic analysis and design for the recommended flood control improvements are in accordance with procedures in EM 1110-2-1601, "Hydraulic Design of Flood Control Channels." Background information on the project was obtained from Mill Creek historical records documented in "Report on Engineering Aspects--Floods of January and February 1969," (compiled in 1974 by the Los Angeles District) and from field data found at local archives. The recommended project plan is designed to contain all flood discharges up to the Standard Project Flood of 33,000 ft^3/s.

Existing Project Conditions

4-02 About 2 miles upstream of the project, Mill Creek flows out of a narrow canyon onto an alluvial fan and divides into a number of smaller channels. A rock outcrop on the left bank just upstream of the project causes the channel to turn to the right. High ground on the right bank confines the debris cone to a narrow channel. Stone masonry floodwalls built in 1938 tie into the left bank rock outcrop and directs the floodflows to the high ground on the right bank (pl. 2). The project reach begins at the existing Corps levee which ties into the masonry floodwall.

4-03 The original Corps project, completed in 1960, consists of a single levee in three segments (total length 2.6 miles) on the south bank of Mill Creek and grading of the channel in the vicinity of the levee. The levee side slope was revetted with grouted stone except for the downstream 1,870 feet (stas. 70+00 to 88+70) where dumped stone was placed on the levee slope. The top of the levee is between 4 and 11 feet above the design grade, and the grouted stone extended to a toe depth at least 7 feet below the design grade. Structures in the project reach included Garnet Street Bridge (sta. 130+00) and two Bear Valley Mutual Water Company aqueducts (levee stas. 68+00 and 196+00).

4-04 Mill Creek Levee confines floodwaters to the extreme right of the alluvial fan, which in recent geologic time has been its natural course. In the flood of 1938, however, before the stone floodwalls were built, a flow split occurred at this location and floodflows were diverted down a

manmade irrigation channel called "The Zanja" on the left side of the fan (pl. 2). Redlands, the major population center on the Mill Creek alluvial fan, sustained damage in 1938 from the flooding Zanja.

4-05 Through the project reach, Mill Creek maintains a slope of about 4 percent. The channel thalweg contacts the levee at the upstream end, but moves to the right side of the channel through the Garnet Street Bridge, and continues on the right side downstream to the Santa Ana River. The existing levee was designed to convey 33,000 ft^3/s with 5 feet of freeboard for bank to bank flow. However, smaller magnitude floods have produced meandering flows which have attacked and damaged the levee.

4-06 Since 1960, the existing levee has prevented floods from damaging the nearby population centers of Mentone and Redlands. But Los Angeles District engineers inspecting the levee during and after major floods have concluded that the levee has failed to perform as intended. The reason for this failure is the instability of the channel bed. Small flows that break away from the main channel transport massive quantities of sediment, including large boulders. Upon contact with the levee, these meandering "cross-channels" deposit ramps of material on the levee slopes, sometimes to the extent that flows overtop the levee. Alternately, these attacking flows scour below the levee toe and cause revetment collapse. Continuing development has increased the need for safe conveyance of Mill Creek floodwaters down the right side of the fan.

Historic Flooding and Remedial Measures

4-07 Five damaging floods occurred on Mill Creek after completion of the original levee project in 1960. Rehabilitation measures were undertaken after each flood and, in 1970, after extensive watershed burns. Historic profiles and cross-sections are shown on plates 21 through 27. Post-project flood events and associated rehabilitation costs are summarized in table IV-1.

HISTORICAL DAMAGE

4-08 Much of the 1965 flood damage was due to the natural phenomena of meandering and braiding. While the main channel safely conveyed most of the flood through the project reach, minor flows broke away at several places and directly contacted the levee. The impingement of these attacking channels caused local scour in some reaches and heavy deposition in others. Near levee station 195+90, the channel scoured 10 feet below the channel elevation at the levee, destroyed a 24-inch diameter pipeline, and then deposited back 7 feet of sediment. At this same location an 8-foot section of levee toe revetment was carried away by the flood. Deposition against the masonry floodwall (upstream from the existing levee) occurred to within 2 feet of its top. Heavy deposition against the levee occurred at several places upstream of Garnet Street between stations 160+00 and 196+00. Minor levee overtopping occurred at locations in this reach where the stream deposited material nearly to the levee top.

Table IV-1. Post Project Flood Events, Rehabilitation.

Original Construction:

Date	COE Design Peak (cfs)	Federal Cost ($)
1960	33,000	$653,720

Damaging Flood Events:

Date	COE Peak[1/] Estimate	USGS Peak[2/] Estimate	Damage Type
22 Nov 1965	6,600	10,000	Levee, pipeline
6 Dec 1966	10,000	10,000	Levee, fence
25 Jan 1969	18,100	35,400	Levee, Garnet St., gabions
25 Feb 1969	18,000	7,500	Levee, gabions
2 Feb 1978	5,400	5,400	Gabions

Rehabilitation:

Date	Type	Federal Cost ($)
1965	Levee repair, channel excavation and grading	$136,000
1967	Levee repair, channel excavation and grading, gabion baffle construction	355,000
1969	Levee repair, channel excavation and grading, gabion repair, additional gabion baffle construction	139,000
1970	Channel excavation, berm construction	345,000
1978	Gabion repair, channel excavation and grading	112,000
	TOTAL	$1,087,000

1/ At Corps of Engineers levee, about 3 miles downstream of U.S.G.S. gauge.

2/ At bridge on State Highway 38.

4-09 Damage in 1966 was very similar to that of 1965 except that it was less severe upstream from Garnet Street and more severe downstream. At Garnet Street, sediment plugged the bridge and was deposited 3 feet thick on the deck. Downstream from Garnet, scour to and below the levee toe caused some revetment damage (pl. 24). Near station 95+00 sediment deposition formed a ramp (see paras. 4-26 to 4-34) allowing about 1,000 ft^3/s to overtop the levee. In addition, part of the ungrouted levee (stas. 75+00 to 77+00) was completely destroyed by the scour action of meandering and braiding flow which had separated from the main channel.

4-10 The flood of January 1969 caused severe deposition in places both upstream and downstream from Garnet Street. Minor overtopping of flows occurred at the upstream location, but flows were diverted back into the channel by high ground. Overtopping flow estimated at 1,000 ft^3/s also occurred in the downstream reach near station 90+00. Garnet Street bridge was flanked by about 1000 ft^3/s which broke away on the upstream left bank and destroyed a section of the roadway approach. Flow through the bridge severely undermined but did not topple the downstream gabion deflection baffles (see para. 4-14).

4-11 A second 1969 flood, in February, continued some of the damage of the January flood. The flow overtopped the levee again downstream of Garnet Street, and gabions were undermined in additional places. The ungrouted downstream end of the existing levee (stas. 70+00 to 73+00) was completely destroyed by the scour action of meandering and braiding flow which had separated from the main channel.

4-12 Flooding in February of 1978 caused minor damage. The gabion deflection baffles placed upstream of Garnet Street after the 1969 flooding were undermined but did not topple.

REHABILITATION

4-13 After each flood the levee was restored to its original condition (table IV-1). Extensive channel work was performed to hinder meandering and braiding patterns. A pilot channel was excavated after each flood, and the material used to regrade the channel to remove "cross-channels" and restore a 2.5 percent slope streamward from the levee. In 1970, excavated material was also used to construct a berm on the north side of the floodplain in an effort to disrupt the "cross-channel" patterns.

4-14 After the 1966 flooding, further structural measures were undertaken to try to prevent "cross-channels" from setting up and directly attacking the levee. Downstream of Garnet Street two gabion deflection baffles were constructed. The length totaled about 1,500 feet. In 1969 these gabion structures were repaired ard lengthened another 750 feet and an additional 1100 feet of gabion deflection baffles were placed upstream of Garnet Street (pl. 2). The upstream baffles were repaired after the 1978 flood severely undermined them.

4-15 Damages from historic post-project floods on Mill Creek have been almost exclusively incurred to flood control structures such as the levee or gabion deflection baffles. Only the damage to Garnet Street in 1969 and to a private fence in 1966 were unrelated to flood control structures.

RECOMMENDED PROJECT

4-16 The recommended project (pls. 3 through 14) is an improvement of the original project required to assure conveyance of the standard project flood. The recommended project will contain the design discharge of 33,000 ft^3/s; provide for long term aggradation, degradation trends; and control local scour and deposition.

4-17 The components of the recommended project are:

a. Raising the top of the existing levee between station 70+00, the downstream end of the project, and station 88+70. The levee will be raised 4 feet at station 70+00 and taper to a 0 height increase at station 88+70.

b. Grouting the riprap levee face between stations 70+00 and 88+70.

c. Extending the existing levee toe an average of 7.5 feet between stations 70+00 and 129+33.33, an average of 8.5 feet between stations 130+72 and 155+00 and an average of 10 feet between stations 155+00 and 196+25.37 the upstream end of the project.

d. Constructing a vertical floodwall, average height of 6 feet, on top of the levee from stations 70+00 to 130+20 and from stations 130+72 to 196+25.37.

e. Restoring a 100-foot strip of streambed adjacent to the levee to within 7 to 10 feet of the top of the levee. This strip will be maintained after each flood event.

4-18 The vertical floodwall will provide a minimum of 9.5 feet of freeboard above the main channel SPF water surface, a minimum of 8.2 feet above the main channel energy grade line, a minimum of 4.5 feet above the water surface for the impinging flow channel attacking the levee, and a minimum of 2.5 feet above the energy grade line of that water surface (see para. 4-31).

4-19 The recommended project eliminates the need for further gabion baffles construction and repair. The "line of protection" provided by the levee with the proposed project in place is designed to withstand direct attack from cross-channels.

4-20 The need for excavation of pilot channels and extensive streambed grading after each flood is also eliminated by the recommended project. While some grading will be required, it will be limited to the 100-foot strip of streambed next to the levee. This grading will function more to reduce the starting elevation of ramping deposition on levee slopes (see paras. 4-26 through 4-34), than to hinder cross channels.

4-21 Analysis of historic scour at the levee was the basis for determination of required levee toe depth (pls. 3 through 11). The recommended toe elevation was established by identifying the maximum historic depth of scour and providing an additional depth of 5 feet to account for uncertainties. The streambed elevation at the levee will be maintained between 7 and 10 feet vertically below the top of the levee. The 7-foot upper limit was set to insure that the floodwall will not be overtopped by flows due to ramping. Whereas, the 10-foot lower limit was set to insure that the revetment will not fail due to local scour. The downstream reach (stas. 70+00 to 88+70) is aggrading, the streambed will be maintained at the minimum 7 feet vertical depth from the top of levee. In the upstream reach (stas. 160+00 to 196+25) the streambed is degrading, so the streambed will be maintained at a maximum depth of 10 feet below the top of the levee.

Streambed Analysis

GENERAL

4-22 On Mill Creek, the primary cause of flooding problems is undesirable sediment movement. Floodwaters are comprised not only of rapidly flowing water, but also of a range of flowing sediment from fine sand to large boulders. During a flood the stream will alternately scour and deposit material depending on rapidly fluctuating sediment transport capacity. The creek's ability to move large quantities of boulders, in particular, has been a cause for concern. An analysis of sedimentation trends on Mill Creek was conducted as an essential factor in the hydraulic design. Aggradation and degradation are long-term sedimentation processes.

4-23 If the streambed was stable, the water surface of the Standard Project Flood would be 3.7 feet below the top of the existing levee (pls. 21 through 26). This water surface was calculated using the Corps program HEC-2, with cross-sections spaced an average of 400 feet apart, and Manning's n-values in the range of .07 to .09. The high n-values reflect not only the predominance of large diameter material, but also braided channel bedforms. In addition, a sensitivity analysis on roughness showed that the water surface, often approaching critical depth, is not highly sensitive to the choice of n-value. Aggradation, however, increases the water surface. Degradation increases the ability of the stream to undercut the existing levee toe. A final threat to successful functioning of Mill Creek Levee has been a phenomenon called "sediment ramping", which is discussed in paragraphs 4-26 to 4-34.

HISTORIC TRENDS

4-24 Trends of aggradation and degradation were analyzed by comparing the topography of three different years: 1958 Corps mapping from the original project, San Bernardino County mapping (dated 1964 downstream from Garnet Street and 1967 upstream from Garnet Street), and 1987 Corps mapping. The streambed was divided into 80 cross-sections, showing

change in streambed elevation over a 30-year period. Plate 27, for example, shows that at a cross-section near levee station 96+00 (downstream from Garnet Street) channel aggradation is a steady trend. Table IV-2 summarizes the results for the entire project reach. The predicted 100-year trend is computed by taking the average trend over the 30 years of record, adjusting for estimated human impact, and multiplying by 1.5 (a factor to account for uncertainty). During its 30-year lifetime the existing project has experienced a 50-year flood, two 27-year floods, and three other floods greater than 12-year in frequency. The predicted 100-year aggradation and degradation trends were derived by considering this full range of normal streambed activity. Human impacts include Garnet Street roadway and bridge, channel excavation and grading, and gabion deflection baffles.

IMPACT ON DESIGN

4-25 The Mill Creek hydraulic design accounts for aggradation and degradation trends in the following ways: the levee will be raised four feet above its existing height at station 70+00, transitioning to the existing top of levee at station 88+70. This will offset the high aggradation trend at the lower end of the project. Wall heights will not in general reflect aggradation trends. The overriding factor in levee overtopping, and thereby the wall height, is not aggradation, but rather the sediment-ramping effect discussed in the next section (paras. 4-26 through 4-34). In addition, the freeboard will account for the general instability of the streambed. Degradation, however, is accounted for in the design of the levee toe depth.

Sediment Ramping

PHENOMENON DESCRIPTION

4-26 The flow in Mill Creek is typical of high-gradient natural streams. It is highly unstable, nearly always subcritical but approaching critical depth. Chutes of supercritical flow develop, but are short and intermittent. The stream, instead of flowing supercritically straight down the alluvial fan slope, breaks from the steeper path, curving to less steep cross-fan slopes. The flow continuously scours and deposits sediment as it meanders and divides into braided channels.

4-27 The phenomenon of "sediment ramping" occurs when a meandering channel contacts the levee. During floods larger than about 5,000 ft^3/s, the meandering and braiding action of the stream causes smaller flows to break away from the main channel. These smaller flows generally scour and meander their own channels and often come in contact with the levee. Upon initial contact, a sudden change in flow direction causes local scour. This material, in addition to the incoming sediment load, gives the stream its full sediment capacity.

Table IV-2. Summary of Aggradation and Degradation Trends.*

Station	100-year trend (channel)	100-year trend (levee)	Station	100-year trend (channel)	100-year trend (levee)
70+00 to 75+00	+3.5	+3.8	130+00 to 135+00	-3.0	+4.5
75+00 to 80+00	+5.5	+3.8	135+00 to 140+00	-3.0	+3.5
80+00 to 85+00	+5.5	0.0	140+00 to 145+00	-4.5	+3.0
85+00 to 90+00	+4.5	+1.8	145+00 to 150+00	-4.5	+4.8
90+00 to 95+00	+5.3	+1.5	150+00 to 155+00	-4.5	+4.5
95+00 to 100+00	+5.3	-0.8	155+00 to 160+00	-4.5	+3.8
100+00 to 105+00	+4.8	-4.5	160+00 to 165+00	-3.8	-2.3
105+00 to 110+00	+2.0	0.0	165+00 to 170+00	-3.8	-1.5
110+00 to 115+00	+0.8	+4.5	170+00 to 175+00	-4.5	-3.0
115+00 to 120+00	-3.0	0.0	175+00 to 180+00	-4.5	-2.3
120+00 to 125+00	-1.5	+2.3	180+00 to 185+00	-4.5	-3.0
			185+00 to 190+00	-3.8	0.0
			190+00 to 195+00	-4.5	-1.5

*The 100-year trend is the average predicted change in elevation of the channel bed in feet. The column for channel values indicates the trend for the main channel only and does not include the full bank to bank floodplain. The column for levee values indicates the trend for the 100-foot strip of streambed next to the levee. Human impacts have been accounted for and include the following: bridge and roadway, channel excavation and grading, and gabion deflection baffles.

4-28 Such attacking channels have been observed to carry flows up to a few thousand ft^3/s with bottom widths up to 50 feet. They curve away from the main channel at angles near 25 degrees on slopes in the range of .035 to .05. Attacking channel flow is highly unstable, undulating and breaking into whitewater. As it flows parallel to the levee, sediment begins to drop out and a natural levee forms on the channelward side. The attacking channel thus confines itself to the levee until it regains the scour capacity to break from its own levee formation. Another factor in deflecting the attacking channel back toward the main channel is that the longer this channel remains confined to the levee the steeper the channelward slopes become.

4-29 The steepening channelward slope is due to the fact that deposition by the attacking channel not only builds a natural levee but also a rising invert or ramp (see para. 4-30). The quantity and extent of the deposition in the form of a ramp is a function of the duration of flow. The resulting profile slope of the attacking channel flattens gradually during the flood. Field observations of actual ramps at Mill Creek have shown that the ramp tends to approach a .02 slope. Since the top of levee slope is about .04, the flatter ramp slope will intersect the top of levee at some downstream location. As a result the flow on the ramp overtops the levee.

HYDRAULIC ANALYSIS OF SEDIMENT RAMPING

4-30 The purpose of the sediment ramping analysis is to determine required wall height, which is a function of ramp length. A ramp with a 2 percent slope will "rise" to meet the top of levee (4 percent slope) at a rate of 2 feet vertically per 100 horizontally. Note that the ramp slope is not adverse. Given the elevation that ramping begins (the streambed elevation at the levee), and the length that a ramp will reach during a flood, the required wall height may be calculated.

4-31 Ramp length is a function of the full flood hydrograph (discharge and duration), the attack channel hydrograph, sediment discharge, and sediment volume required for ramp and natural levee building. The Standard Project Flood predicted ramp length was determined in the following manner:

a. A typical attacking channel size, shape, and slope was estimated from field observation, historical data, and attacking channel discharge. Ten percent of the total design flow was used to calculate the sediment volume for the levee ramp.

b. Sediment discharge was computed using the best available equation (Meyer-Peter), calibrated with Mill Creek flood data. Since two 50-year floods have occurred on Mill Creek since the existing levee was constructed, the sediment discharge equation was adjusted to match observed ramps. It was then used to compute the SPF sediment discharge.

c. Sediment accumulation resulted because incoming sediment discharge was calculated to be more than outgoing (due to flattening slope). The difference between incoming and outgoing

was the sediment discharge available for ramp and natural levee building. This sediment volume was calculated from the sediment accumulation hydrograph by dividing by the flood duration.

d. Historical field data indicated that the ramp tends to approach a 0.02 slope, so ramp volume was computed as a function of ramp length and size of typical attacking channel. By trial and error a ramp length of 170 feet was determined.

e. The maximum height of the ramping channel water surface was determined by calculating critical depth at the flood peak. The water surface for SPF resulted in a depth above the existing levee top of 1.4 feet. The corresponding height of the energy grade line above the top of the levee was 3.5 feet.

IMPACT ON DESIGN

4-32 A floodwall was chosen as the best engineering solution to prevent levee overtopping. A vertical wall face will be more effective in deflecting the attacking flow into the channel. Field observations have concluded that sediment does not climb as well against a wall as on a sloping levee face.

4-33 The ramp length was calculated assuming an initial streambed elevation of 7 feet below the top of levee, which is true for much of the project reach, since the design requires maintenance of this minimum 7-foot clearance for a 100-foot strip of streambed next to the levee.

4-34 Freeboard was incorporated into the wall height calculation. A 6-foot wall provides freeboard of 4.5 feet above the water surface and 2.5 feet above the energy grade line. This accounts for uncertainties in the calculations as well as for the general instability of the streambed.

V. GEOLOGY, SOILS AND MATERIALS

Regional Geologic Setting

5-01 The Mill Creek Valley is located at the southern base of the San Bernardino Mountains, which are in the eastern part of the Transverse Ranges physiographic province. The Transverse Ranges province is an elongated geomorphic and structural unit that trends essentially east-west, and is made up of chains of parallel mountain ranges and valleys extending from Point Arguello eastward to the southern Mojave Desert. The principal geomorphic and structural features of the Transverse Ranges lie across the grain of adjacent physiographic provinces, which are strongly influenced by the northwest-southeast-trending San Andreas fault system (pl. 28). Within and bounding the Transverse Ranges province are other major fault zones that have been active during the same span of geologic time that the San Andreas system has been active. Rock units within the province are represented by Precambrian plutonic and metamorphic types, and complex sections of Cretaceous and younger plutonic and sedimentary rocks.

Site Topography and Geology

5-02 The project is located in an east-west trending valley which extends from the mouth of Mill Creek Canyon on the east to the Mill Creek/Santa Ana River confluence on the west. The valley is bounded by the San Bernardino Mountains on the north and the Crafton Hills on the south, and is 1 to 2 miles wide. Elevations in the project area vary from 1,800 to 2,300 feet above NGVD, with a westward gradient of about 220 feet per mile. The existing structures are founded primarily on recent alluvium deposited by Mill Creek in a strip less than 1,000 feet wide along the center of the valley. Quaternary alluvium is exposed in the remaining portion of the valley floor, underlying the Recent alluvium and resting on bedrock. The total thickness of alluvium is generally 100 to 200 feet along the center of the valley. In the vicinity of the levees at Garnet Street, however, there are occasional exposures of bedrock, consisting of Precambrian pelona schist and Tertiary quartz monzonite.

Faulting and Seismicity

5-03 The region surrounding the project is highly faulted and tectonically active (pls. 29 and 30). The Crafton fault, a northeast-trending normal fault, extends under the project structure near Garnet Street. This fault is part of the Crafton Hills horst and graben complex, which has been active in both Pleistocene and Recent time. The south branch of the San Andreas fault is located about a mile north of the project, and is the dominant seismic feature in the area. This stretch of the San Andreas fault has exhibited a slip rate of as much as 25 mm/yr., and is considered capable of a maximum credible earthquake of magnitude 8+. Assuming an epicenter 1 mile from the project, a peak ground acceleration exceeding 0.7 g could occur at the site during such an event (U.S. Army Corps of Engineers, SPD, 1979).

Groundwater

5-04 Groundwater levels along the project alignment are directly affected by flows in Mill Creek and the underlying alluvium. Seasonal runoff appears to be the controlling factor in the geohydrology of the project site; groundwater levels drop during the winter period of snow accumulation and little runoff, and then tend to recover during late spring and summer snowmelt. In general, high groundwater levels have occurred from March through October, when depths to water may be as little as 10 to 15 feet below the streambed. The lowest levels occur from November through February, and may drop to as much as 150 feet below the surface. Groundwater pumping for irrigation, discharge from powerhouses, and diversions for irrigation, domestic use, and spreading all occur throughout the year at various locations in the valley, and may modify the normal patterns. Groundwater elevations may vary considerably in the vicinity of Garnet Street, due to the presence of the Crafton fault groundwater barrier. Groundwater levels tend to be uniform across the fault at depths of 10 to 15 feet, however, when the depth to groundwater is 20 feet or more upstream of the fault, the groundwater level downstream may drop as low as 80 feet below the streambed.

Investigations

PREVIOUS INVESTIGATIONS

5-05 Prior to design and construction of the levees in 1960, the foundation conditions at the project site were determined by visual observation of the streambed surface and the existing cut banks in the project reach. The foundation materials were observed to be recent alluvium consisting of streambed sand, gravel, cobbles, and boulders up to approximately 3 feet in diameter. The larger materials were more abundant in the upstream portion of the project.

RECENT INVESTIGATIONS

5-06 An investigation of the pervious borrow area for Seven Oaks Dam was conducted in October 1986. This investigation is considered to be representative of Mill Creek foundation conditions due to their close proximity and the similarity between material types of both sites. The area investigated is located approximately 1 mile downstream of the Mill Creek Levee project site at the confluence of Mill Creek and the Santa Ana River.

5-07 Five test pits were excavated to depths ranging from 18 to 24 feet using a Cat 235 tracked backhoe with a 4-foot wide bucket. Since the deposits were observed to be uniform with depth, samples were obtained by scraping the vertical walls of the pit and then cleaning out the materials which fell to the bottom of the pit. Approximately 40,000 pounds of material was removed from each pit for soils testing.

INVESTIGATION DURING ADVERTISING PERIOD

5-08 In order to better ascertain the material types to be excavated at Mill Creek, test trenches will be excavated during the contract advertising period. The trenches will be located as close to the levee toe as reasonably possible and will be spaced far enough apart to represent the entire levee reach. Testing of the materials obtained from the trenches will not be required; the trenches are intended to provide the contractor with a visual evaluation only. A visual observation of the material types will allow contractors to determine the extent of processing that will be required to provide floodwall backfill and stone for the grouted stone revetment.

Field and Laboratory Testing Results

5-09 Mass gradations were determined for the materials sampled from the Seven Oaks Dam pervious borrow area. The gradation of plus 3-inch material was determined in the field. Results indicate that the materials larger than 3 inches range from 49 to 59 percent of the total sample. The maximum size of the rock in the samples ranges from 20 to 36 inches in diameter; however, rocks up to 60 inches in diameter were excavated from the test pits. Gradations of the minus 3-inch materials were determined at the South Pacific Division laboratory and at the Los Angeles District laboratory. The minus 3-inch materials classified as gravelly sands (SP).

5-10 Maximum dry densities for the minus 3-inch portions of the samples were determined using vibratory compaction methods (ASTM D 4253). The results indicate that the average maximum dry density for the minus 3-inch material is about 132 pcf.

5-11 Consolidated drained and consolidated undrained triaxial compression tests were conducted on 12-inch diameter samples of gravelly sand, compacted to 95 percent of maximum density at 3 percent over optimum moisture content. The tests were run at confining pressures of 1, 2.5, 5, and 10 tsf, and the pore pressures were monitored during the

undrained tests. The maximum size particle in these tests was 2 inches. The results indicate a Ø' angle of 40.5 degrees for the consolidated drained tests, and a Ø' angle of 36.5 degrees for the consolidated undrained tests with pore pressure measurements.

Design Values

FOUNDATION

5-12 Design values for the Mill Creek Levee foundation are based upon tests conducted on the Seven Oaks Dam pervious borrow materials. A Ø angle of 36 degrees was conservatively assumed for the foundation materials. The in situ density of the foundation is assumed to be 135.0 pcf at a moisture content of 8 percent. The density of the foundation for saturated conditions is assumed to be 145.0 pcf.

EMBANKMENT AND TOE BACKFILL

5-13 The existing Mill Creek Levee was constructed with materials obtained from the required riverbed excavation as will the proposed levee enlargement. The design values for the existing levee embankment, the proposed levee enlargement and the toe backfill are assumed to be the same as those presented above for the levee foundation due to the similarity of material types. The maximum allowable bearing capacity of the levee for the proposed floodwall is 6,000 pounds per square foot and the coefficient of friction between the concrete floodwall and the levee materials is 0.6.

Stability Analysis

5-14 A typical levee section with the recommended modifications, landward side slopes of 1V on 2H and river side slopes of 1V on 2.25H, was analyzed for slope stability (assuming a levee height of 16 feet). Saturated conditions were not considered in the analysis because of relatively low groundwater and grouted side slopes which will prevent major seepage into the levee from floodflows. The end of construction case was analyzed for the river side slope using a computer aided circular search which employs Spencer's procedure. The factor of safety for stability was calculated to be 1.9. Additionally, the river side slope was analyzed for surficial slides using the infinite slope method and the factor of safety was calculated to be 1.6.

Construction Considerations

EXCAVATION

5-15 Temporary slopes for the required streambed excavation at the levee toe and for the levee excavation (i.e., for the floodwall) will be no steeper than 1V on 1H. Bedrock may occur within the excavation limits in the vicinity of Garnet Street, and will consist of hard, dense

schist and granitic rocks. Since excavation will be for placement of revetment for protection of the levee toes, excavation will be terminated at bedrock.

PLACEMENT AND COMPACTION

5-16 Compacted fill, if required, will be obtained from the riverbed. The fill will be specified to have a maximum particle size of 9 inches and will be placed in 12-inch layers. Each layer will be compacted to 95 percent of maximum density (ASTM D 4253). Any materials removed from the existing levee embankment during the floodwall construction will be replaced and compacted as stated above.

SLOPE PROTECTION

5-17 The stone to be used for the grouted stone slope protection will be well graded and range in size from 4 inches to 12 inches.

Construction Materials

BORROW MATERIAL SOURCES

5-18 Materials required for borrow can be obtained from the riverbed in the area of the required toe excavation. Processing of these materials will be required in order to remove stone which exceeds the maximum stone size requirement. Oversized stone can be disposed of in the levee toe backfill, provided it is not placed directly against the grouted stone revetment.

STONE MATERIALS

5-19 There are six quarries (table V-1) within 30 miles of the project which have recently produced stone suitable for use on Corps of Engineers' projects.

Table V-1. Stone Sources.

Quarry	Rock Type	Distance to Project (mi.)	Specific Gravity (BSSD)	Test Date
Atkinson	granite	21	2.77	10/87
Declesville	granite	24	2.79	11/83
Harlow	andesite	28	2.66	6/85
Juniper Flats	diorite	21	2.74	7/83
Slover Mountain	marble	13	2.72	11/83
	metasediment		2.90	11/83
Stringfellow	granite	23	2.66	10/85

Stone for revetment may be obtained from these sources, as well as other nearby quarries with suitable test results or service records. The alluvium along the Mill Creek channel contains as much as 50 percent over 6-inch material, and may be processed to produce rock for grouted stone revetment.

Concrete Materials

STRUCTURAL ELEMENTS

5-20 Structural elements to be constructed of concrete for the Mill Creek Levee will be a concrete floodwall and grouted stone slope protection.

5-21 The recommended floodwall for the levee will be constructed along the existing top of levee from: station 88+70 to station 130+20 and from station 130+72 to station 196+25.37, and on top of the new raised levee from station 70+00 to station 88+70.

5-22 The height of the wall varies from 5 feet 11 inches to 7 feet 6 inches. The wall is designed as an inverted T-wall. The footing will be 6 feet in length and will rest on top of the levee. The thickness of the stem and footing will be 8 inches and 10 inches respectively. A cutoff wall, 3 feet deep and 10 inches thick, will be provided at the end of the footing (river side). See plate 14 for a typical floodwall section.

5-23 Grouted stone revetment will be constructed from station 70+00 to station 88+70. The toe will be about 18 feet below the new top of the levee and will have a thickness of 18 inches. Additionally, the existing grouted stone toe revetment from station 88+70 to station 129+33.33 and station 130+72 to station 196+25.37 will be extended. From station 88+70 to station 129+33.33 the new toe depth will vary from 2 to 8 feet below the existing toe with a thickness of 18 inches. From station 130+72 to station 196+25.37 the new toe depth will vary from 8 to 12.5 feet below the existing toe with a thickness of 18 inches.

5-24 The following table summarizes the approximate quantities of concrete, grout and cements to be used in project construction:

Table V-2. Estimated Concrete Material Quantities.

	Concrete (yd^3)	Grout (yd^3)	Cement* (CWT)
Walls	1,920	-	-
Footing and Stems	2,330	-	-
Cutoff Walls	850	-	-
Grouted Revetment	-	6,680	47,070

* Calculated for Grouted Revetment Only.

CLIMATIC CONDITIONS

5-25 The climate of the Mill Creek Levee drainage area is subtropical semi-arid with warm summers and relatively mild winters. From late spring through mid-fall, with the greatest intensities during the summer, the channel area is subject to air pollution accumulation between the late morning and early evening. Variations in the climate are almost entirely due to seasonal changes.

5-26 The area is generally mild, free from extremely low winter temperatures and relatively immune to extremely high summer temperatures. Summers are pleasantly warm, with daily maximum temperatures averaging around 95°F (extreme highs around 115°F) and nocturnal minimums ranging from 36°F to near 58°F. Winters are cool, with mild days. Normal daily winter temperatures range from highs of 68°F to lows of 37°F (all-time extremes from 17°F to 93°F).

5-27 The relative humidity in the Mill Creek Levee area can vary from zero to 100 percent. Typical ranges during most of the year are from 80 to 90 percent during the early morning hours and 30 to 50 percent during the early afternoon.

5-28 Mean seasonal precipitation in the drainage area is approximately 32 inches. The primary rainy season is winter (November-April), with the heaviest precipitation occurring normally from December through mid-March. Summer (June-September) is the driest time of the year.

CEMENTS

Cement Sources

5-29 There are a relatively large number of cement producers in and near the Los Angeles Basin which are capable of supplying cement certified by the Corps of Engineers ongoing cement certification program. Among these plants are the Califorinia Portland Cement Company plant at Colton, the Kaiser Cement Company plant at Lucerne Valley, the Southwestern Cement Company plant at Victorville, and the Riverside Cement Company plant at Riverside. All of these plants are in the State of California. The following paragraphs summarize the types of cements which these plants produce. Table V-3 supplies prices of various cements from the sources specified, and table V-4 contains cost data on the shipping of cement.

5-30 The California Portland Cement Company plant at Colton, located approximately 15 miles west of the project site produces Type II and III cements conforming to the requirements of ASTM C 150.

5-31 The Kaiser Cement Company plant in the Lucerne Valley, located approximately 55 miles north of the project site produces Type II cement conforming to the requirements of ASTM C 150. This plant also produces a blended cement conforming to the requirements of ASTM C 595, Type IP.

5-32 The Riverside Cement Company plant at Oro Grande, California, located approximately 53 miles north of the project site produces Type II cement conforming to the requirements of ASTM C 150.

5-33 The Southwestern Cement Company plant at Victorville, California, located approximately 50 miles north of the project site produces Type II and V cements conforming to the requirements of ASTM C 150.

Table V-3. Cement Prices.
(Dollars Per Ton, FOB Plant, December 1987)

Cement Plant and Location	CEMENT TYPE			
	IP	II	III	V
California Portland, Colton	-	$73.00	$78.00	-
Kaiser, Lucerne Valley	$74.30	60.00	-	-
Southwestern, Victorville	-	64.00	-	$80.30
Riverside Cement, Riverside	-	63.00	-	-

Table V-4. Cement Shipping Prices.
(Dollars Per Ton, December 1987)

Distance (Miles)	Cost	Distance (Miles)	Cost	Distance (Miles)	Cost
3-5	$3.142	30-35	$4.480	70-80	$7.828
5-10	3.296	35-40	5.200	80-90	8.446
10-15	3.450	40-45	5.922	90-100	9.012
15-20	3.760	45-50	6.386	100-110	9.682
20-25	3.966	50-60	6.902	110-120	10.300
25-30	4.224	60-70	7.314	120-130	11.072

Pozzolans

5-34 ETL 1110-1-127, dated 17 August 1984, allows the use of flyash in concrete construction except in those cases where its use can be proven to be undesirable. The local practice of the ready-mix concrete industry is to use flyashes as pozzolanic admixtures in concrete. The reason for this is the reduction of heat of hydration, reduction in cost due to the price of flyashes in comparison to the price of cement, increase in workability at lower water contents, and the reduction in the alkali-aggregate reaction. The practice of local agencies is to specify Type F flyash generally conforming to the requirements of ASTM C 618. The Corps of Engineers has recently started a program to evaluate the quality and uniformity of flyashes and has set up a certification plan similar to the one used for cements. Materials conforming to these requirements are produced at the plants shown on plate 31. The closest local producer, the Western Ash Company, supplies flyash, conforming to the requirements of ASTM C 628, Type F, from a plant at Page, Arizona. A local distribution point is at San Bernardino, California approximately 12 miles west of the project site. F type ash would be available from this source at a cost of $40 per ton.

AGGREGATES

5-35 The Waterways Experiment Station Technical Memorandum No. 6-370, September 1953, titled "Test Data, Concrete Aggregates in Continental United States," Volume 1, Area 3, Western United States, indicates that the vicinity of the Mill Creek Levee project has a large number of sources capable of producing aggregates suitable for use in concrete construction. In accordance with EM 1110-2-2000 some of these sources were sampled and tested at the South Pacific Division Laboratory by the Los Angeles District in the Spring of 1985. The names and locations of the sources are shown on plate 31.

5-36 Testing consisted of petrographic analysis, elementary physical tests, tests for potential reactivity of aggregates and a concrete check mix. The tests indicate that aggregates suitable for use in all aspects of concrete construction are available from local sources. The results of the laboratory work are reported hereafter.

Geologic Aspects of Aggregate Sources

GENERAL

5-37 All aggregates from suppliers listed herein are mined from major streambeds on the alluvial plains several miles downstream from the southern margin of the San Bernardino Mountains. The aggregates are processed from alluvium which is derived from rocks exposed in the mountain regions surrounding the streams and their tributaries. The igneous and metamorphic basement complex of the San Bernardino Mountains is the most abundant terrane in the source area, consequently most of the aggregate is composed of those rock types.

LYTLE CREEK

5-38 Both Owl Rock Company and Fourth Street Crusher are located in the Lytle Creek streambed, 4 and 6 miles downstream from the mouth of the Lytle Creek Canyon, respectively. Most of the rocks in the Lytle Creek basin are Tertiary diorite, Cretaceous granite and diorite, pre-Cretaceous pelona schist, and various Precambrian metamorphic rocks. The granite, granodiorite, and diorite predominate in samples from these suppliers, along with significant amounts of schist, gneiss, quartizite, and various metasedimentary and metavolcanic rocks. Minor amounts of gabbro are also present, from Mesozoic exposures west of the canyon. Fine aggregate (No. 4 and smaller) produced from these two sources contain fragments of all of the above rocks, along with individual grains of hornblende, quartz, biotite and feldspars.

SANTA ANA RIVER

5-39 The C. L. Pharris Company is located in the Santa Ana River streambed approximately 5 miles downstream from the mouth of the Santa Ana River Canyon. This source was previously operated by the Livingston-Graham Company. Rock exposed in the Santa Ana River drainage consists mainly of Mesozoic intrusives and Precambrian igneous and metamorphic rocks. Rock produced at the C. L. Pharris plant is predominantly Mesozoic diorite, granodiorite, and gabbro, along with Precambrian schist. A small proportion of sandstone and siltstone fragments is also present, derived from scattered outcrops of Tertiary sediments. Fine aggregate consists of individual grains of feldspar, quartz, and biotite, with some fragments of granite, quartzite, schist, and metasedimentary rocks.

SAN GORGONIO RIVER

5-40 The Beaumont Concrete Company is located in the San Gorgonio River floodplain about 6 miles downstream from the mouth of San Gorgonio River Canyon. Aggregate produced by this supplier is composed primarily of Mesozoic granite, granodiorite, gabbro, and diorite. Pelona schist is also present, as well as gneiss and miscellaneous metamorphic lithologies probably derived from Precambrian outcrops. Fine aggregate from the Beaumont Concrete Company contains all of the above rock types as well as individual grains of the constituent mineral.

Aggregate Sources

OWL ROCK PRODUCTS

5-41 This source is on Lytle Creek approximately 7 miles west of the project site. The location of this source is shown on plate 31. This source excavates alluvial sands and gravels from the Lytle Creek streambed deposits. Samples of aggregates were obtained from this source in 1985 and were tested at the SPD Laboratory. Aggregate test results are shown in table V-5 and in figure 2.

5-42 At the time of the sampling the plant was producing three rock sizes and a washed concrete sand, which were sampled for testing. The course sized materials included 2-, 1-1/2-, and 3/8-inch topsize materials. The 2-inch material meets the Standard Specifications for Public Works Construction (SSPWC), a local specifying group made up of public agencies and suppliers, specifications size No. 2, and ASTM C 33, size No. 4. The 1-1/2-inch material meets the SSPWC specifications size No. 3 and ASTM C 33 size No. 56. The 3/8-inch material meets the SSPWC size No. 4 but does not meet any ASTM size standard. The washed concrete sand conforms to both the SSPWC and ASTM C 33 size for washed concrete sand. Gradations determined from the samples taken are shown in table V-5.

5-43 The rock sizes tested had specific gravities (Sp. Gr.) of 2.65 to 2.67 with Sp. Gr. of 2.67 and above for aggregates greater than 3/4-inch in size. The sand had a Sp. Gr. of 2.63. The aggregates had absorptions of 1.0 to 1.9 percent for the coarse and 1.6 percent for the fines. The coarse aggregate has an abrasion loss of 24 percent when tested in accordance with ASTM C 131, using gradation A. The chemical method of reactivity of aggregates was performed and the results are shown in figure 2. The test results indicate that there should be no unfavorable reactions between cements and the aggregates. The aggregates are generally of slightly higher quality than those found in the Los Angeles Basin, but are about average for the local San Bernardino area.

4TH STREET CRUSHER

5-44 This source is on Lytle Creek approximately 15 miles west of the project site. This source excavates alluvial sands and gravels from Lytle Creek streambed deposits near its confluence with the Santa Ana River. The location of this source is shown on plate 31. Samples of aggregates were obtained from this source in 1985 and were tested at the SPD Laboratory. Aggregate test results are shown in table V-6 and figures 3 and 4.

5-45 At the time of sampling, the plant was producing three rock sizes and a washed concrete sand, which were sampled for testing. The coarse sized materials included 2-, 1-1/2-, and 3/8-inch topsize materials. The 2-inch material meets SSPWC specifications size No. 2, and ASTM C 33, size No. 4. The 1-1/2-inch material met the ASTM C 33 size No. 56 and barely failed the SSPWC size No. 3 on the 3/8 inch screen. The 3/8-inch material does not meet any size standard. The washed concrete sand conforms to both the SSPWC and ASTM C 33 size for washed concrete sand. Gradations determined from the samples taken are shown in table V-6.

5-46 The rock sizes tested had Sp. Gr. of 2.65 to 2.69 with Sp. Gr. of 2.68 and above for aggregates greater than 3/4-inch in size. The sand had a Sp. Gr. of 2.63. The aggregates had absorptions of 1.0 to 1.6 percent for the coarse and 1.2 percent for the fines. The coarse aggregate has an abrasion loss of 25 percent when tested in accordance with ASTM C 131, using gradation A. The chemical method of reactivity of aggregates was performed and the results are shown in figure 3.

Table V-5. Physical Tests on Concrete Aggregates for:

OWL ROCK PRODUCTS COMPANY
Riverside Avenue at Linda Street
Rialto, California
(Date tested: January 1985)

Part A: GRADATIONS IN PERCENT FINER BY WEIGHT

Sieve Size	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
2 in.	100			
1-1/2 in.	96	100		
1 in.	23	98		
3/4 in.	2	74		
1/2 in.		31		
3/8 in.		14	100	100
No. 4		4	4	99
No. 8				82
No. 16				63
No. 30				41
No. 50				19
No. 100				7
No. 200				3

Part B: PHYSICAL TEST RESULTS

Test Requirement	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
Specific Gravity	2.67	2.67	2.65	2.63
Absorption	1.0	1.6	1.9	1.6
Soft Particles	.	0.20	0.40	.

Part C: PHYSICAL TESTS ON COMBINED SAMPLES

Organic Impurities (ASTM C 40)		OK
Mortar Strength ratio @ 7 days (ASTM C 87)		
Soundness: Magnesium Sulfate (ASTM C 88)		
Coarse Aggregate	3/4"-1-1/2"	1.35
Fine Aggregate	3/8"-3/4"	3.18
Decantation (ASTM C 117)		14.50
Abrasion Loss, 500 rev. (ASTM C 131)		
Grading Designation		A
Percent Loss		24
Reactivity, Chemical Method (ASTM C 289)		
Coarse Aggregate	Rc= 36 Sc= 29	Innocuous
Fine Aggregate	Rc= 51 Sc= 43	Innocuous

Table V-6. Physical Tests on Concrete Aggregates for:

4TH STREET CRUSHER
1945 W. 4TH Street on Lytle Creek
Rialto, California
(Date tested: January 1985)

Part A: GRADATIONS IN PERCENT FINER BY WEIGHT

Sieve Size	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
2 in.	100			
1-1/2 in.	97	100		
1 in.	27	99		
3/4 in.	2	66		
1/2 in.		22		
3/8 in.		4	100	100
No. 4			8	97
No. 8				86
No. 16				68
No. 30				41
No. 50				18
No. 100				6
No. 200				2

Part B: PHYSICAL TEST RESULTS

Test Requirement	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
Specific Gravity	2.69	2.68	2.65	2.63
Absorption	1.0	1.1	1.6	1.2
Soft Particles	.	1.3	0.1	.

Part C: PHYSICAL TESTS ON COMBINED SAMPLES

Organic Impurities (ASTM C 40)					
Mortar Strength ratio @ 7 days (ASTM C 87)					
Soundness: Magnesium Sulfate (ASTM C 88)					
Coarse Aggregate	3/4"-1-1/2"				1.5
	#4-3/4"				2.3
Fine Aggregate					12.6
Decantation (ASTM C 117)					
Abrasion Loss, 500 rev. (ASTM C 131)					
Grading Designation					A
Percent Loss					25
Reactivity, Chemical Method (ASTM C 289)					
Coarse Aggregate	Rc=	49	Sc=	20	Innocuous
Fine Aggregate	Rc=	28	Sc=	27	Innocuous

The test results indicate that there should be no unfavorable reactions between cements and the aggregates. Mortar bar test results show expansion of +0.025 percent at 180 days and +0.012 percent at 335 days for high alkali cement. Expansions of +0.009 percent at 180 days and 360 days are noted for low alkali cements. Detailed results are shown in figure 4. The aggregates are generally of slightly higher quality than those found in the Los Angeles Basin, but are about average for the local San Bernardino area.

5-47 Subsequent review of this source in December 1987 indicated that the pit was no longer able to produce coarse aggregates. The only material being produced from the pit at this time was a concrete sand. Large size materials are periodically washed into the pit as a result of streamflows. The extended drought has introduced no coarse size materials into the pit, and as a consequence this source at this time does not supply coarse aggregates. If materials are deposited subsequent to this report it is anticipated that they will have properties similar to those described herein. In accordance with SPD criteria, this source and or any other source used in construction will be subject to verification testing.

BEAUMONT CONCRETE COMPANY

5-48 This source is near Cabazon approximately 10 miles southeast of the project site. This source excavates alluvial sands and gravels. The location of this source is shown on plate 31. Samples of aggregates were obtained from this source in 1985 and were tested at the SPD Laboratory. Aggregate test results are shown in table V-7 and figures 5 and 6.

5-49 At the time of sampling, the plant was producing three rock sizes and a washed concrete sand, which were sampled for testing. The coarse sized materials included 2-, 1-1/2-, and 3/8-inch topsize materials. The 2-inch material meets the SSPWC specifications size No. 2, and ASTM C 33, size No. 4. The 1-1/2-inch material meets the SSPWC specifications size No. 3 and ASTM C 33 size No. 56. The 3/8-inch material does not meet any size standard. The washed concrete sand conforms to both the SSPWC and ASTM C 33 size for washed concrete sand. Gradations determined from the samples taken are shown in table V-7.

5-50 The rock sizes tested had Sp. Gr. of 2.63 to 2.67 with Sp. Gr. of 2.68 and above for aggregates greater than 3/4-inch in size. The sand had a Sp. Gr. of 2.66. The aggregates had absorptions of 1.0 to 2.7 percent for the coarse and 1.2 percent for the fines. The coarse aggregate has an abrasion loss of 39.1 percent when tested in accordance with ASTM C 131, using gradation A. This result is slightly higher than desired but conforms to ASTM and SSPWC requirements. The chemical method of reactivity of aggregates was performed and the results are shown in figure 5. Mortar bar test results show expansion of +0.044 percent at 180 days and +0.040 percent at 335 days for high alkali cements. A peak expansion of +0.046 percent at 225 days was noted.

Table V-7. Physical Tests on Concrete Aggregates for:

BEAUMONT CONCRETE COMPANY
Cabazon Pit
San Gorgonio River at Apache Trail
Cabazon, California
(Date tested: January 1985)

Part A: GRADATIONS IN PERCENT FINER BY WEIGHT

Sieve Size	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
2 in.	100			
1-1/2 in.	94	100		
1 in.	21	99		
3/4 in.	2	74	100	
1/2 in.		33	99	
3/8 in.		11	56	100
No. 4		2		99
No. 8				86
No. 16				66
No. 30				43
No. 50				19
No. 100				6
No. 200				2

Part B: PHYSICAL TEST RESULTS

Test Requirement	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
Specific Gravity	2.66	2.67	2.63	2.66
Absorption	1.0	1.3	2.7	1.2
Soft Particles	0.0	0.0	0.0	.

Part C: PHYSICAL TESTS ON COMBINED SAMPLES

Organic Impurities (ASTM C 40)		
Mortar Strength ratio @ 7 days (ASTM C 87)		
Soundness: Magnesium Sulfate (ASTM C 88)		
Coarse Aggregate	3/4"-1-1/2"	1.9
	#4-3/4"	2.5
Fine Aggregate		16.1
Decantation (ASTM C 117)		
Abrasion Loss, 500 rev. (ASTM C 131)		
Grading Designation		A
Percent Loss		39.1
Reactivity, Chemical Method (ASTM C 289)		
Coarse Aggregate	Rc= 36 Sc= 29	Innocuous
Fine Aggregate	Rc= 51 Sc= 43	Innocuous

Expansions of +0.012 percent at 180 days and +0.014 percent at 335 days with a peak of +0.016 percent at 55 days were noted for low alkali cements. Detailed results are shown in figure 6. Although the values are below the limits for expansion, +0.05 percent at 180 days and +0.10 percent at 360 days in accordance with EM 1110-2-2000, these reaction results are much higher than most results in the Los Angeles District. Use of these aggregates may require special requirements.

C. L. PHARRIS

5-51 This source is on the Santa Ana River approximately 6 miles west of the project site. This source was previously identified as Livingston Graham. This source excavates alluvial sands and gravels from Santa Ana River streambed deposits. The location of this source is shown on plate 31. Samples of aggregates were obtained from this source in 1985 and were tested at the SPD Laboratory. Aggregate test results are shown in table V-8 and figures 7 and 8.

5-52 At the time of sampling, the plant was producing three rock sizes and a washed concrete sand, which were sampled for testing. The coarse sized materials included 2-, 1-1/2-, and 3/8-inch topsize materials. The 2-inch material meets the SSPWC specifications size No. 2, and ASTM C 33, size No. 4. The 1-1/2-inch material failed the SSPWC specifications for size No. 3 on the 3/8-inch screen, but meets ASTM C 33 size No. 56. The 3/8-inch material does not meet any size standard. The washed concrete sand failed both the SSPWC and ASTM C 33 size for washed concrete sand due to the presence of excess fines. Gradations determined from the samples taken are shown in table V-8.

5-53 The rock sizes tested had Sp. Gr. of 2.62 to 2.66 with Sp. Gr. of 2.65 and above for aggregates greater than 3/4-inch in size. The sand had a Sp. Gr. of 2.63. The aggregates had absorptions of 0.8 to 1.7 percent for the coarse and 1.1 percent for the fines. The coarse aggregate has an abrasion loss of 32.7 percent when tested in accordance with ASTM C 131, using gradation A. The chemical method of reactivity of aggregates was performed and the results are shown in figure 7. The test results indicate that there should be no unfavorable reactions between cements and the aggregates. Mortar bar test results show expansions of +0.025 percent at 180 days and +0.015 percent at 335 days with a peak of +0.030 percent at 235 days for high alkali cement. Expansions of +0.021 percent at 180 days and +0.013 percent at 335 days are noted for low alkali cements. Detailed results are shown in figure 8. The aggregates are generally of slightly higher quality than those found in the Los Angeles Basin, but are about average for the local San Bernardino area.

Table V-8. Physical Tests on Concrete Aggregates for:

C. L. PHARRIS
E. of Norton AFB
San Bernardino, California
(Date tested: January 1985)

Part A: GRADATIONS IN PERCENT FINER BY WEIGHT

Sieve Size	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
2 in.	100			
1-1/2 in.	95	100		
1 in.	18	99		
3/4 in.	1	70	100	
1/2 in.	1	23	99	
3/8 in.		3	10	100
No. 4		1		98
No. 8				88
No. 16				70
No. 30				41
No. 50				17
No. 100				6
No. 200				6

Part B: PHYSICAL TEST RESULTS

Test Requirement	1.5" - 3.0"	3/4" - 1.5"	#4 - 3/4"	Fine Agg.
Specific Gravity	2.66	2.65	2.62	2.63
Absorption	0.8	0.9	1.7	1.1
Soft Particles	0.0	1.5	0.3	

Part C: PHYSICAL TESTS ON COMBINED SAMPLES

Organic Impurities (ASTM C 40)		OK	
Mortar Strength ratio @ 7 days (ASTM C 87)			
Soundness: Magnesium Sulfate (ASTM C 88)			
Coarse Aggregate	3/4"-1-1/2		0.5
	#4-3/4		1.9
Fine Aggregate			10.4
Decantation (ASTM C 117)			
Abrasion Loss, 500 rev. (ASTM C 131)			
Grading Designation			A
Percent Loss			32.7
Reactivity, Chemical Method (ASTM C 289)			
Coarse Aggregate	Rc= 41 Sc= 26		Innocuous
Fine Aggregate	Rc= 51 Sc= 24		Innocuous

Aggregate Costs

5-54 Estimated unit costs of aggregate for use in construction of the Mill Creek Levee are given in the following table. The quantities reflect materials to be used in the structural concrete work but do not reflect materials to be used in grout for grouted stone. The differences in tonnages of materials reflect differences in producer specific mix designs and material properties. The producers selected mix designs according to the following criteria. The mixes were to be pumpable with 1-1/2-inch maximum size aggregate.

Table V-9. Estimated Unit Costs For Concrete Aggregates. (January 1988 prices)

		Tons	Haul Distance Miles	Unit Cost $/Ton
C. L. Pharris	Coarse	7,250	6	5.50
	Sand	5,165	-	5.00
Owl Rock	Coarse	7,670	17	4.95
	Sand	4,700	-	4.55
Beaumont Concrete	Coarse	6,550	10	4.40
	Sand	5,740	-	4.40
4th Street Crusher	Coarse	6,830	15	N/A
	Sand	4,820	-	8.00

Additionally, approximately 6,570 tons of sand will be needed for grout for the grouted stone requirements of the project.

Water

5-55 Sufficient water suitable for preparation of concrete is available from commercial sources at the concrete production facilities cited above. During geotechnical explorations for the Seven Oaks Dam, groundwater observed in one of the trenches upon drying, left a white residue. It is believed that the residue may be calcium or carbonate based. Further studies for Seven Oaks Dam will include studies to determine the exact composition of this residue. For construction of the Mill Creek Levee, water will be required to conform to the requirements of CRD C-400, and a low alkali cement is recommended.

Admixtures

5-56 A wide variety of chemical admixtures are used in southern California. Based on the structural elements to be constructed, only the simplest admixtures will be specified. These will include air entraining agents, and water reducing and retarding admixtures. No specific need for high range water reducing admixtures or "Superplasticizers" has been identified.

Mix Design Requirements

5-57 Specifications for concrete and concrete mix designs for construction of the Mill Creek Levee will be developed to meet the requirements of ER 1110-2-1150. Specific design requirements will be developed based on the information supplied in EM 1110-2-2000 and will consider the types of structures and the anticipated exposure conditions to which they will be subjected.

5-58 The types of structures to be constructed for the project described above are relatively simple and the Los Angeles District has extensive experience in construction of these types of structural elements.

5-59 Based on EM 1110-2-2000 the maximum water-cement ratio of all concrete exposed to flowing water shall be limited to 0.45. Additionally, the nominal maximum size coarse aggregate shall be specified as 1-1/2 inches.

5-60 An additional requirement will be a limitation on the maximum placing temperature of the concrete. Based on the ambient weather conditions reported above and the requirements specified in EM 1110-2-2000 the maximum placing temperature of concrete will be limited to $85^{o}F$. As a protection from damage by sunlight to freshly placed concrete, specifications will require that the contractor either shade freshly placed concrete for 3 days or apply an opaque curing compound conforming to the requirements of CRD C-300.

Cost of Concrete

5-61 The following table presents current costs for concrete for construction of the proposed structural elements. Suppliers developed the costs based on a 1-1/2 inch maximum aggregate size concrete mixture which would be pumpable and would supply compressive strengths of 3,000 psi at 28 days. The prices include the cost of delivery to the job site.

Table V-10. Estimated Costs of Redimix Concrete.
(January 1988 Prices)

Supplier	$/cu.yd.
Owl Rock Products	53.00
4th Street Crusher	48.00
Beaumont Concrete	46.00
C. L. Pharris	44.80

Specifications Requirements

5-62 The following information details specification requirements for construction.

CEMENTS

5-63 Cements will be specified to conform to the requirements of ASTM C 150, Type II, low alkali. The low alkali requirement should assist in offsetting any potential alkali-aggregate reactivity. Additionally, Type V cement conforming to the requirements of ASTM C 150 will be specified as an option, although the need for high sulfate resistance has not been specifically identified. Blended cements shall conform to the requirements of ASTM C 595, Type IP. Flyash used to manufacture Type IP cement shall conform to the requirements for pozzolan.

POZZOLANS

5-64 Pozzolans for use in concrete construction will be specified to comply with requirements of ASTM C 618, Type F. The loss on ignition will be limited to 6 percent maximum. Additionally, the optional requirements in table 1A shall be invoked.

ADMIXTURES

5-65 Admixtures for use in concrete construction will be limited to water reducers, retarders, accelerators, and air entraining agents conforming to the following requirements:

a. Water reducing admixtures will conform to the requirements of ASTM C 494, Types A or D.

b. Retarding admixtures will conform to the requirements of ASTM C 494, Types B or D.

c. Accelerating admixtures will conform to the requirements of ASTM C 494, Types C or E. No calcium chloride will be allowed.

d. Air entraining agents will conform to the requirements of ASTM C 260.

AGGREGATES

5-66 Aggregates will be specified to conform to the physical requirements of ASTM C-33. Sizes of coarse aggregates to be used during construction will be selected at the time of preparation of plans and specifications based on materials available in the area at the time of the proposed construction. Sizes will be selected to conform to the requirements of ASTM C 33 or to SSPWC paragraph 200-1.4 and shall be a nominal maximum size of 1-1/2 inches for structural elements over 7-1/2 inches wide, and in which the clear distance between reinforcement bars is at least 2-1/4 inches. All other elements will use a nominal maximum size of 3/4 inches.

5-67 The following sources shall be described as supplying suitable aggregates: (1) existing commercial sources on the Santa Ana River from its confluence with Mill Creek to upstream from the Southern Pacific RR bridge in San Bernardino, (2) existing commercial sources on Lytle Creek and the Cajon Wash to their confluence with the Santa Ana River, and (3) existing commercial sources on the San Gorgonio River downstream from the mouth of the San Gorgonio River Canyon.

References

Bolt, Bruce A., 1987, Seismological Report for Seven Oaks Dam, Report to Los Angeles District Corps of Engineers, Contract No. DACW09-87-M-1734.

California Department of Mines and Geology, 1976, Geologic Hazards in Southwestern San Bernardino County, California, CDMG Special Report 113.

Carson, S.E. and Matti, J.C., 1985, Contour Map Showing Minimum Depth to Groundwater, Upper Santa Ana River Valley, California, 1973-1979, United States Geologic Survey Miscellaneous Field Studies Map MF-1802.

Dibblee, T.W., 1982, Geology of the San Bernardino Mountains, Southern California, in Geology and Mineral Wealth of the California Transverse Ranges, South Coast Geologic Society Annual Symposium and Guidebook No. 10

Fife, D.L., Rodgers, D.A., Chase, G.W., Chapman, P.H., Sprotte, E.C., Morton, D.M., 1976, Geologic Hazards in Southwestern San Bernardino County, California, California Division of Mines and Geology Special Report 113.

Krinitzky, E.L., and Chang, F.K., 1977, Specifying Peak Motions for Design Earthquakes, U.S. Army Engineer Waterways Experiment Station Miscellaneous Paper S-73-1, Report 7.

Krinitzky, E.L., and Marcuson, W. F. III, 1983, Principles for Selecting Earthquake Motions in Engineering Design, in Bulletin of the Association of Engineering Geologists Vol. XX, No. 3., August 1983.

Matti, J.C., Morton, D.M., and Cox, B.F., 1985, Distribution and Geologic Relations of Fault Systems in the Vicinity of the Central Transverse Ranges, Southern California, U.S. Geological Survey Open File Report 85-365.

U.S. Army Corps of Engineers, 1983, Earthquake Design and Analysis for Corps of Engineers Projects, Engineering Regulation ER 1110-2-1806.

U.S. Army Corps of Engineers, South Pacific Division, 1979, Reporting Earthquake Effects, SPD Supplement to Engineering Regulation ER 1110-2-1802.

United States Geologic Survey, 1959, Geology and Groundwater Hydrology of the Mill Creek Area, USGS Open File Report.

VI. STRUCTURAL DESIGN

Floodwall

6-01 A floodwall will be provided along the existing levee between station 70+00 and station 129+33.33 and between station 130+72 and station 196+25.37. The height of the wall above the existing top of levee will vary from approximately 5 feet 11 inches to 7 feet 6 inches according to hydraulic requirements.

6-02 The floodwall will be designed as an inverted T-wall. The footing will be 6 feet in length and will rest on top of the levee. The thickness of the stem and the footing will be 8 inches and 10 inches respectively. A cutoff wall, 3 feet deep and 10 inches thick, will be provided at the end of the footing (river side).

6-03 The applied forces will be the hydrostatic force, the weight of concrete and other surcharges above the base of the wall. Uplift pressure in the base will not be considered because sloping grouted stone protection will be constructed from the existing grouted stone to the wall footing, prohibiting the entrance of water under the wall base. The floodwall loading conditions are shown in figure 9.

6-04 Various water surface elevations will be considered in the design.

References

6-05 The design will be based on accepted engineering practice and will conform to the following Engineering Manuals (EM's), Engineering Technical Letters (ETL's), and Engineering Regulations (ER's):

Reference	Title
EM 1110-1-2101	Working Stresses for Structural Design
EM 1110-2-2000	Standard Practice for Concrete
EM 1110-2-2103	Details of Reinforcement-Hydraulic Structures

EM 1110-2-2502	Retaining Walls, Floodwalls (Draft Edition)
ER 1110-2-1806	Earthquake Design and Analysis for Corps of Engineers Projects
ETL 1110-2-256	Sliding Stability
ETL 1110-2-312	Strength Design Criteria for Reinforced Hydraulic Structures

Other applicable ETL's, EM's (EM 1110-series), draft EM's, and codes listed therin.

Material Properties

6-06 Material properties which will be used in the design of the proposed structures are:

CONCRETE

Ultimate Compressive Strength:

Cast-in-place structures	$f'c = 3{,}000$ psi
Modulus of Elasticity	$Ec = 57{,}000\ (f'c)^{1/2}$

REINFORCING STEEL

Yield Strength for Grade 40 Steel	$f_y = 40{,}000$ psi
Yield Strength for Grade 60 Steel	$f_y = 48{,}000$ psi
Modulus of Elasticity	$E_s = 29{,}000{,}000$ psi

WEIGHT

Concrete = 150 pcf

Water = 62.5 pcf

For the weights and properties of soils, refer to Section V entitled "Geology, Soils and Materials," paragraph 5-12.

VII. RELOCATION OF STREETS, RAILROADS AND UTILITIES

Under the recommended plan of improvements for the Mill Creek Levee, there will be no relocation of streets, railroads or utilities. The Garnet Street bridge, which existed when the original Mill Creek Levee was constructed, will remain in place and will continue to be subject to closure during large floods. The bridge does not endanger the functioning of the flood control project. There are no railroads in the project area. Bear Valley Mutual Water Company aqueducts (stas. 68+00 and 196+00) will not be affected by the project. Other existing utilities were relocated or abandoned when the original Mill Creek Levee was constructed and will not be affected by the proposed improvements.

VIII. ACCESS ROADS

8-01 There are paved access roads on the existing levee system which will be partly removed to construct the floodwall. The roads will be replaced or overlain along the levee top and widened from the existing 9-foot width to 12 feet wide. They will continue to have gated access entrances at the Garnet Street crossing. The paved road width will consist of 4 feet-4 inches of concrete which also serves as the floodwall footing and 7 feet-8 inches of flexible pavement which will be constructed adjoining the footing. The access road will be overlain from station 196+25.37 to station 130+72 and from station 130+20 to station 88+70. The road will be replaced from station 88+70 to station 70+00. A 2 percent cross slope on the access road will provide drainage away from the floodwall. There is an existing drainage system on the landward side of the existing levee.

Geometric Design

8-02 Vehicular access roads, including ramps, will match existing grades and alignment.

Pavement Design Values

8-03 The flexible pavement forming the paved access roads will be designed in accordance with Department of the Army TM 5-822-5. Based on information available in TM 5-825-2 a California Bearing Ratio (CBR) value of 30 can be assigned to the subgrade when the materials are compacted to 95 percent of maximum density as determined in accordance with ASTM D 4253. The road will be used only for operations, maintenance, and inspections and therefore the average number of daily vehicle passes is estimated to be less than 25 on each lane. The traffic to which the road will be exposed will include some small trucks and a few heavy trucks. Based on the above information the flexible pavement will be designed in accordance with the following values:

Category of Traffic	=	III
Class of Road	=	E
Design Index	=	2

8-04 New pavement sections for the access road will consist of a 2-inch asphaltic concrete layer of 4 inches of an aggregate base course over 6 inches of native materials compacted to 95 percent of maximum density. Overlays of the existing pavement would consist of a maximum of a 2-inch and a minimum of a 3/4-inch layer of bituminous surface course. The overlay thickness would be based on the condition of the existing pavement after construction of the floodwall.

IX. ENVIRONMENTAL ANALYSIS

General

9-01 An environmental impact statement on the proposed flood control improvements along the mainstem of the Santa Ana River including Mill Creek was presented in the Phase I General Design Memorandum (GDM) dated September 1980. For this Phase II GDM, the environmental evaluation has been updated and broadened to include the presently proposed floodwall construction on the Mill Creek Levee. Details of the findings and concerns are presented in the Supplemental Environmental Impact Statement included in the Main Report of this Phase II GDM. This section presents a brief description of the environmental impacts which may be brought about as a result of the project. Compensation for impacts are also discussed.

Environmental Impacts

SEDIMENTATION

9-02 The raising of the Mill Creek Levee, along with the additional toe protection will not impact sedimentation. The improvements to the levee will not preclude sedimentation processes from occurring in this area.

WATER RESOURCES

Hydrology and Water Use

9-03 Impacts will not occur to hydrology and water use in this project area.

Water Quality

9-04 Water quality in the area, other than high sediment loads, is very good. No impact to the water quality of the area is expected with this project.

AIR QUALITY

9-05 Impacts to air quality will be local and short term, due to construction activities, and will primarily be associated with vehicle emissions and dust generation. Increased vehicle emissions would result from heavy equipment use on the construction site, from trucks hauling borrow materials to the construction site, and from personal vehicles driven by construction workers.

LAND USE AND SOCIAL CONCERNS

Prime and Unique Farmlands

9-06 No farmlands are located within or adjacent to the project area.

Recreation

9-07 There is no recreation associated with this project feature. The maintenance road at the top of the levee will be gated and locked; public access will not be allowed.

Growth Inducement

9-08 Growth inducement as a result of the improvement to the existing Mill Creek Levee is a possibility. Although land adjacent to the levee is mostly owned by water districts and agencies, improved protection on land side of the levee may increase growth in the newly protected area.

TRANSPORTATION AND UTILITIES

Facilities

9-09 No streets, railroads or utilities will be relocated. The Garnet Street bridge will not be impacted.

Access

9-10 Paved access roads to the existing levee will be removed during construction, but will be replaced along the levee top as gated roads for operation and maintenance purposes.

Transport of Borrow Materials

9-11 Borrow materials will be obtained from within 100 feet of the existing levee on the riverside. No public roads will be used for transport of borrow materials. There will not be any excess excavation materials to be disposed of.

NOISE

9-12 The Mill Creek area is a relatively undisturbed area, with some human-induced noise present due to the presence of Highway 38 which runs along a part of the levee. The project will have local short-term impacts to the environment, as construction-related noise will be present.

BIOLOGICAL RESOURCES

9-13 Alluvial scrub vegetation, located in the streambed, will be impacted by construction activities, along with minor amounts of juniper woodland and mulefat. The construction area on both sides of Garnet Avenue also includes scattered cottonwoods and sycamores. Wildlife currently utilizing habitat within the construction zone will be temporarily displaced.

9-14 The recommended improvements of Mill Creek Levee will result in impacts to a small group (50 to 70 plants) of the Santa Ana River Woolly-Star (Eriastrum densifolium sanctorum), an endangered species. There are no other known populations of any endangered or threatened species which will be impacted. Additional surveys within the vicinity of Mill Creek were conducted during spring 1988 for the slender-horned spineflower (Centrostegia). No additional populations of either species were found during these surveys.

9-15 Compensation for impacts to Eriastrum are covered under the discussion for Seven Oaks Dam, Volume 1, and are included in that project feature.

CULTURAL RESOURCES

9-16 The construction of improvements to the levee will result in the destruction of two non-significant historic sites. Two potentially significant resources (active aqueduct pipelines) are in the area. Construction plans are to avoid these two active aqueduct pipelines. Both pipelines are located outside the project construction limits. The Bear Valley Highline is located just upstream from station 196+25.37 and the Redlands Adequduct is just downstream from station 70+00 (pl. 2).

9-17 There is currently no proposed cultural resources mitigation for the Mill Creek element of the project.

Site Restoration

9-18 Replanting for the temporary loss of habitat, esthetic values, and for site restoration within Mill Creek, resulting from the recommended project will consist of reseeding disturbed areas with appropriate species following completion of all work. Seeding will be accomplished by broadcast seeding followed by harrowing. Hydroseeding will not be acceptable as it does not encourage good seed to soil contact. In addition, cottonwoods, sycamores, willows, and junipers which occur within the 200-foot zone of construction but outside of the excavation zone will be avoided and protected from construction impacts. Any of these trees which are impacted by construction will be replaced with 5-gallon container plants. In addition to a small amount of Eriastrum, the following species will be in the seed mix at the indicated rates: (1) Lotus scoparius, 6 lbs/acre; (2) Eriogonum fasciculatum, 10 lbs/acre; (3) Encelia farinosa, 3 lbs/acre; (4) Adenostoma fasciculatum,

4 lbs/acre; (5) _Salvia apiana_, 2 lbs/acre; (6) _Artemesia californica_, 2 lbs/acre; (7) _Baccharis glutinosa_, 2 lbs/acre; and (8) _Eriodictyon trichocalyx_, 3 lbs/acre.

X. DIVERSION AND CONTROL OF WATER DURING CONSTRUCTION

Available climatological information indicates that most of the annual rainfall in the Mill Creek drainage area occurs between November and April. To avoid flood damages, construction on the toe extension will be scheduled to take place during the 6 month period between April and October. The low flows in Mill Creek generally occur in the incised channel north of the existing levee and the construction area. Extension of the levee toe can be accomplished during the summer months when the flood threat is minimal; all other construction will take place on the top of the levee, except for any borrow stockpiles produced from the required toe excavation. Measures for diversion and control of water would, therefore, be minimal.

XI. REAL ESTATE REQUIREMENTS

11-01 The Mill Creek Levee begins just above the point where it enters the Santa Ana River and terminates at a point approximately 13,600 feet upstream. It was designed to protect the cities of Mentone and Redlands and surrounding urban areas. The material for raising the will come from the required excavations. The County of San Bernardino already owns the required land area, which were acquired for the construction of the existing Federal flood control project.

11-02 Construction operations for the recommended Mill Creek Levee improvements will occur within existing project rights-of-way.

XII. COST ESTIMATES

12-01 The cost estimates are based on unit price data from recent bids for various items of work on other projects and on unit prices derived using established estimating procedures. In accordance with EM 1110-2-1301, a 15 percent contingency is added to the estimated construction cost. The cost for engineering and design, and supervision and administration was estimated to be 10 percent and 6 percent, respectively, of the construction costs (including contingencies). These percentages are based on the actual prevailing rates experienced by the Los Angeles District Office.

First Cost

12-02 The first cost of the proposed Mill Creek Levee is presently estimated at $5,109,000 (table XII-1). The detailed estimate of the first cost is shown on table XII-2.

Operation and Maintenance

12-03 Upon completion of the proposed flood control improvements, the annual operation and maintenance cost is estimated at $15,000, which is based on the costs incurred by the San Bernardino County Flood Control District for operation and maintenance of the original Mill Creek Levee. This estimated cost is comparable to the actual costs on similar types of improvements experienced by the Los Angeles District.

Comparison of Estimates

12-04 The first cost for the Mill Creek Levee estimated in the Phase I GDM dated September 1980 (October 1979 Price Level) and this same cost escalated to October 1987 price levels is shown in table XII-3. Compared to the escalated Phase I GDM estimate, the present estimate is $19,832,798 lower. The differences between the escalated Phase I GDM estimate and the current estimate are explained as follows:

a. Levee. A decrease of $5,086,082 is due to the elimination of 1.2 miles of levee extension.

b. Floodwall. An increase of $1,578,800 is due to the addition of 2.6 miles of concrete floodwall.

c. Groins. A decrease of $14,738,519 is due to the elimination of groins.

d. Engineering and Design. A decrease of $1,009,957 is due to a decrease in construction costs.

e. Supervision and Administration. A decrease of $706,040 is due to a decrease in construction costs.

f. Operation and Maintenance Manual. An increase of $20,000 is due to the addition of an Operation and Maintenance Manual.

g. Lands and Damages. A decrease of $91,000 is due to the reduction in real estate requirements.

h. Preconstruction Engineering and Design. An increase of $200,000 is due to the addition of preconstruction costs previously included in the Engineering and Design Costs.

Table XII-1. Summary of First Cost.
(October 1987 Price Level)

Acct. No.	Description	Amount
	Construction	
11.0	Levee	$2,635,600
11.0	Floodwall	1,578,800
30.0	Engineering and Design	421,500
31.0	Supervision and Administration	253,100
51.22	Operation and Maintenance Manual	20,000
	Total, Construction	$4,909,000
	Preconstruction Engineering and Design	$ 200,000
	Total, Flood Control First Cost	$5,109,000

Table XII-2. Detailed Estimate of First Cost.
(October 1987 Price Level)

Cost Acct. No.	Item	Quantity	Unit	Unit Cost	Subtotal
11.0	Levee				
	Clearing and Grubbing	2	Acre	$5,324.00	$10,648
	Excavation, Toe	101,000	CY	3.00	303,000
	Compacted Fill, Levee	3,000	CY	6.00	18,000
	Backfill, Toe	101,110	CY	5.00	505,550
	Stone	26,720	Ton	19.00	507,680
	Grout	6,680	CY	80.00	534,400
	Cement	47,070	CWT	5.00	235,350
	AC Pavement	1,210	Ton	60.00	72,600
	Prime Coat	96,400	SF	0.10	9,640
	AC Removal	5,950	SY	1.50	8,925
	Site Restoration	1	Job	L.S.	86,000
	Subtotal, Levee				$2,291,793
	Contingencies				343,807
	Total, Levee				$2,635,600
11.0	Floodwall				
	Exc. Wall Footing and Cutoff	3,110	CY	3.00	9,330
	Wall Concrete	1,920	CY	350.00	672,000
	Footing and Stem Concrete	2,330	CY	130.00	302,900
	Cutoff Wall Concrete	850	CY	90.00	76,500
	Reinforcing Steel	454,840	Lb	0.50	227,420
	.125"x6" Fibrous Mastic	3,320	LF	4.20	13,944
	Steel Door 3'-6"x5'-9"x.5"	2	Ea	350.00	700
	Ladder Rungs	57	Ea	19.00	1,083
	.5"x12" Premolded Exp. Jt.	12,500	LF	2.00	25,000
	Esthetic Treatment	1	Job	LS	44,000
	Subtotal, Floodwall				$1,372,877
	Contingencies				205,923
	Total, Floodwall				$1,578,800
30.0	Engineering and Design (10%)				421,500

Table XII-2. (Continued)

Cost Acct. No.	Item	Quantity	Unit	Unit Cost	Subtotal
31.0	Supervision and Administration (6%)				253,100
51.22	Operation and Maintenance Manual				$ 20,000
	Total, Construction				$4,909,000
	Preconstruction Engineering and Design				$ 200,000
	Total, Flood Control First Cost				$5,109,000

Table XII-3. Comparison of First Cost.

Cost Acct. No.		Phase I GDM Estimate (October 1979 Price Levels)	Phase I GDM Estimate (October 1987 Price Levels)	Present Estimate (October 1987 Price Levels)
11.0	Levees			
	Diversion & Control of Water	$ 12,500	$ 18,598	$ 0
	Clearing & Grubbing	17,500	26,036	12,226
	Excavation	31,250	46,494	348,435
	Fill	188,750	280,822	602,071
	Grouted Stone	4,940,000	7,349,732	1,469,047
	AC Pavement and Prime Coat	0	0	104,821
	Site Restoration	0	0	99,000
	Total, Levees	5,190,000	7,721,682	2,635,600
11.0	Floodwall	0	0	1,578,800
16.0	Groins	9,906,250	14,738,519	0
	Subtotal	15,096,250	22,460,201	4,214,400
30.0	Engineering and Design	1,056,737	1,431,457	421,500
31.0	Supervision & Administration	754,813	959,140	253,100
51.22	Operation & Maintenance Manual	0	0	20,000
	Total, Construction	16,907,800	24,850,798	4,909,000
	Total, Lands and Damages	61,000	91,000	0
	Preconstruction Engineering and Design	*	*	200,000
	Total, Flood Control First Cost	$16,968,800	$24,941,798	$5,109,000

*Included in the Engineering and Design Costs.

XIII. DESIGN AND CONSTRUCTION SCHEDULE

13-01 Preparation of Plans and Specifications. Preparation of contract plans and specifications for the construction of the proposed flood control project will be initiated after the Phase II GDM for the Santa Ana River is approved. Contract plans and specifications will take about 18 months to complete.

13-02 Construction Schedule. Construction of the project will be scheduled to start in the spring of year 2. Construction of the levee improvements including the concrete floodwall will take approximately 12 months. Table XIII-1 shows a generalized construction schedule. The schedule shown may be modified as required based on total project requirements. The overall project construction schedule is provided in the main report.

13-03 Total Funds Required by Fiscal Years. Total funds including Federal and non-Federal share which will be required for the preparation of contract plans and specifications and for construction are shown in the Main Report. Table XIII-1 shows the total construction estimate and an undated schedule.

LINE NO	UNIFORM COST CLASSIFICATION	FEATURE ITEMS	PROJECT COST ESTIMATE	TOTAL AS OF
1	11	LEVEE	2,635.6	
2	11	FLOODWALL	1,578.8	
3	30	ENGINEERING AND DESIGN	421.5	
4	31	SUPERVISION AND ADMINISTRATION	253.1	
5	51.22	OPERATION AND MAINTENANCE MANUAL	20	
6				
7		TOTAL, CONSTRUCTION	4,909	
8				
9		PRE-CONSTRUCTION ENGINEERING & DESIGN	200	
10				
11		TOTAL, FLOOD CONTROL FIRST COST	5,109	
12				
13				
14				
15				
16				
17				
18				
19				
20				
21				
22				
23				
24				
25				
26				
27				

FUNDS IN THOUSANDS OF DOLLARS

DESIGN NO ACTIVITY CONSTRUCTION

SPL FORM 1 NOV 72 571

19			AL AS OF	FY 19				FY 19				FY 19				FY 19				FY 19				FY 19				FY 19				BALANCE TO COMPLETE
Q	3Q	4Q		1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	1Q	2Q	3Q	4Q	

TABLE XIII-1

MILL CREEK LEVEE

DESIGN AND CONSTRUCTION SCHEDULE

U.S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

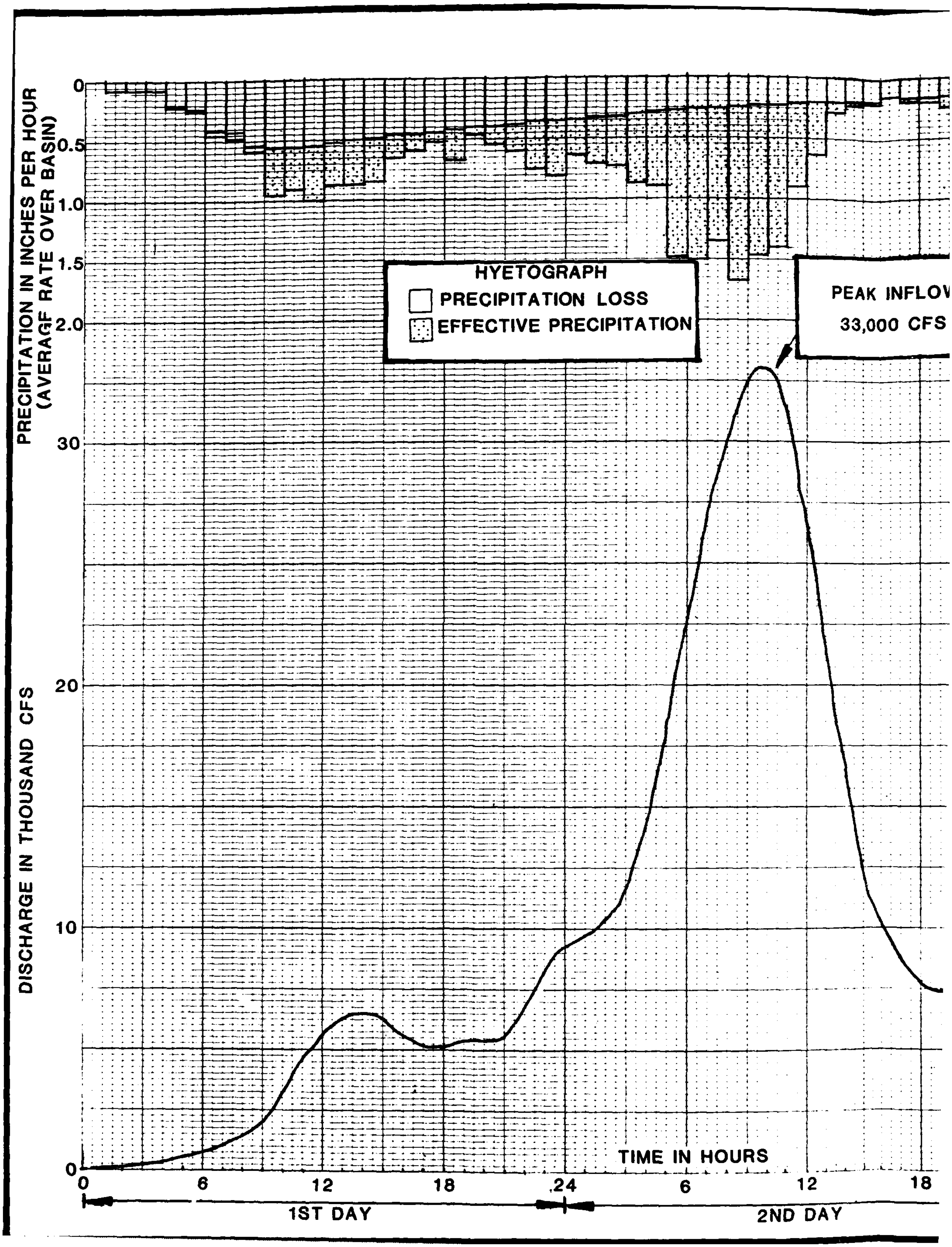
TO ACCOMPANY DESIGN MEMORANDUM NO.
DATED APRIL 1988 SHEET 1 OF 1

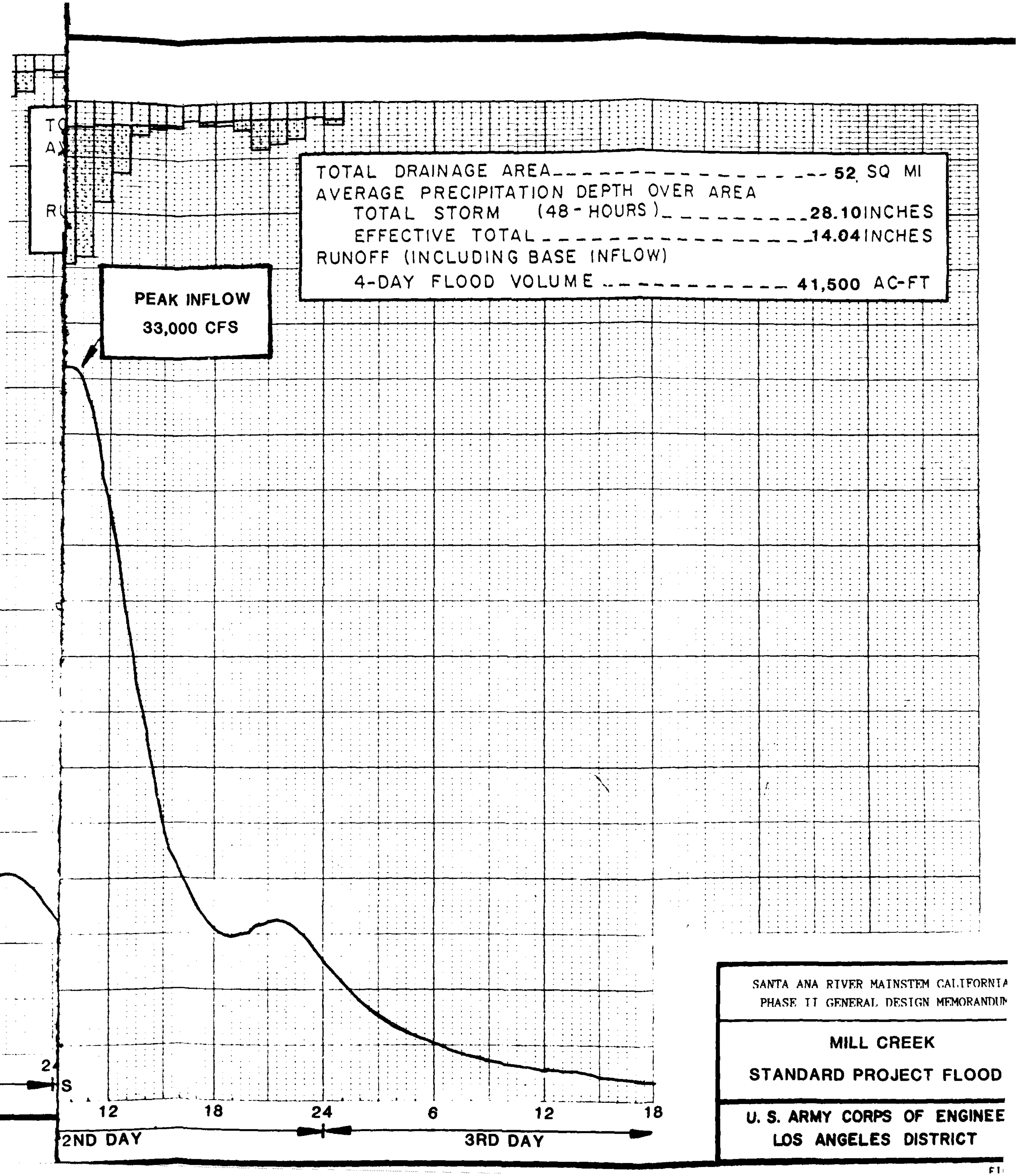
XIV. OPERATION AND MAINTENANCE

14-01 The existing operation and maintenance (O&M) manual would be updated after construction of the flood control improvements in accordance with ER 1130-2-304 "Project Operations" and applicable provisions of ER 1150-2-301 "Local Cooperation." The estimated cost of an updated O&M manual is $20,000. Upon completion of the proposed flood control improvements, the annual operation and maintenance cost is estimated at $15,000, which is based on the costs incurred by the San Bernardino County Flood Control District for operation and maintenance of the existing Mill Creek Levee. This estimated cost is comparable to the actual costs on similar types of improvements experienced by the Los Angeles District. The local sponsors would be responsible for the operation and maintenance of the flood control improvements. The major items of operation and maintenance and their estimated annual costs are shown in table XIV-1.

Table XIV-1. Annual Operation and Maintenance Cost.
(October 1987 Price Levels)

Description	Amount
Operation	
Condition surveys	$1,000
Supervision and administration	2,000
Maintenance	
Debris removal and maintenance	3,000
Maintenance of 100-foot strip of streambed	3,000
Major replacement	
Acces road overlay (20 years)	4,000
Subtotal	13,000
Contingency (15%)	2,000
Total	$15,000


PRECIPITATION IN INCHES PER HOUR (AVERAGE RATE OVER BASIN)
0
0.5
1.0
1.5
2.0
HYETOGRAPH
PRECIPITATION LOSS
EFFECTIVE PRECIPITATION
PEAK INFLOW
33,000 CFS
DISCHARGE IN THOUSAND CFS
30
20
10
0
TIME IN HOURS
0
6
12
18
24
6
12
18
1ST DAY
2ND DAY

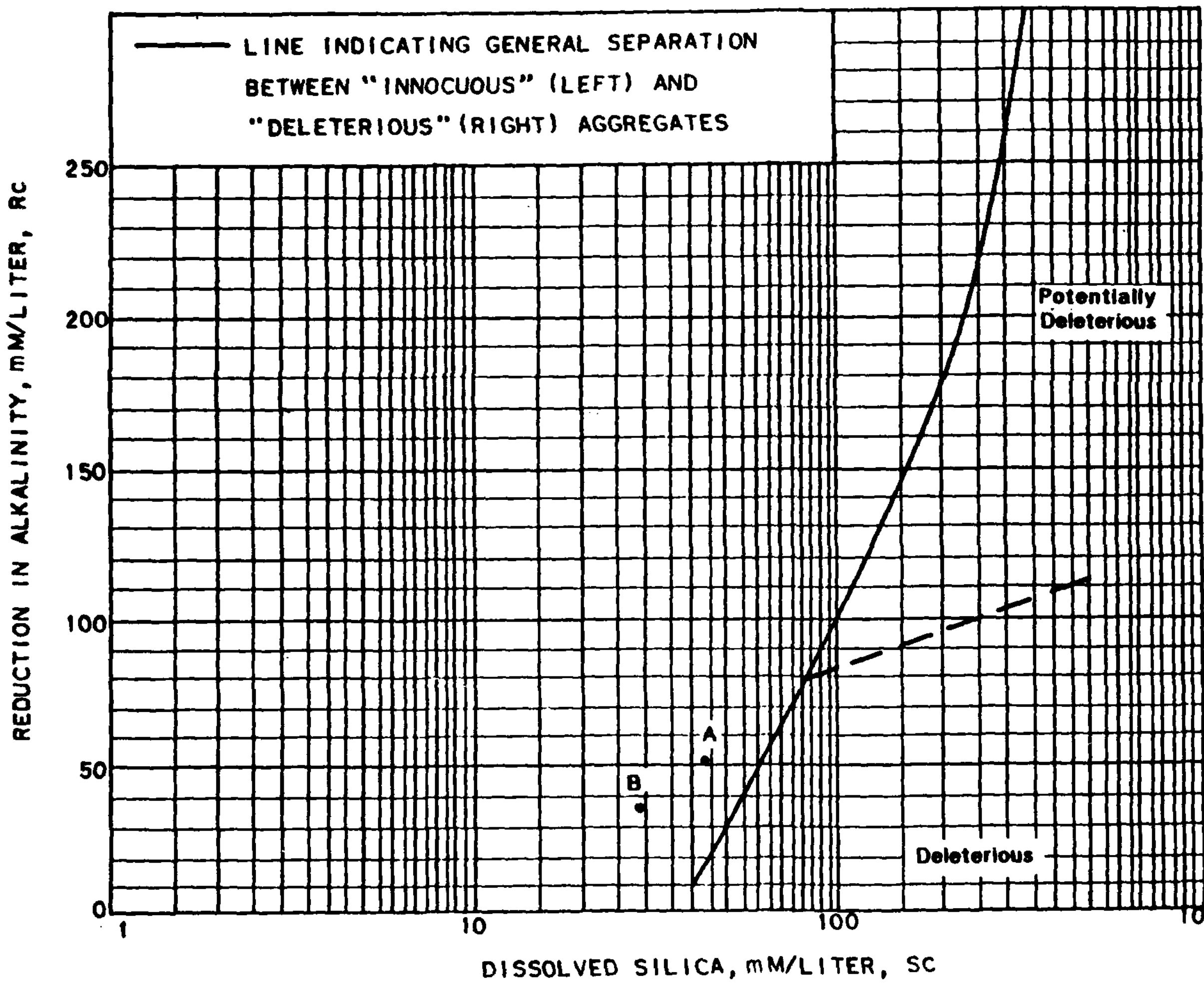


SANTA ANA RIVER MAINSTEM CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK
STANDARD PROJECT FLOOD

U. S. ARMY CORPS OF ENGINEE
LOS ANGELES DISTRICT

CORPS OF ENGINEERS, U. S. ARMY, South Pacific DIVISION.



PROJECT: MILL CREEK LEVEE
Owl Rock Company
Fine & Coarse Aggregate
METHOD CRD-C 128

LEGEND

A - Fine aggregate
B - Coarse aggregate

POINT	Sc	Rc

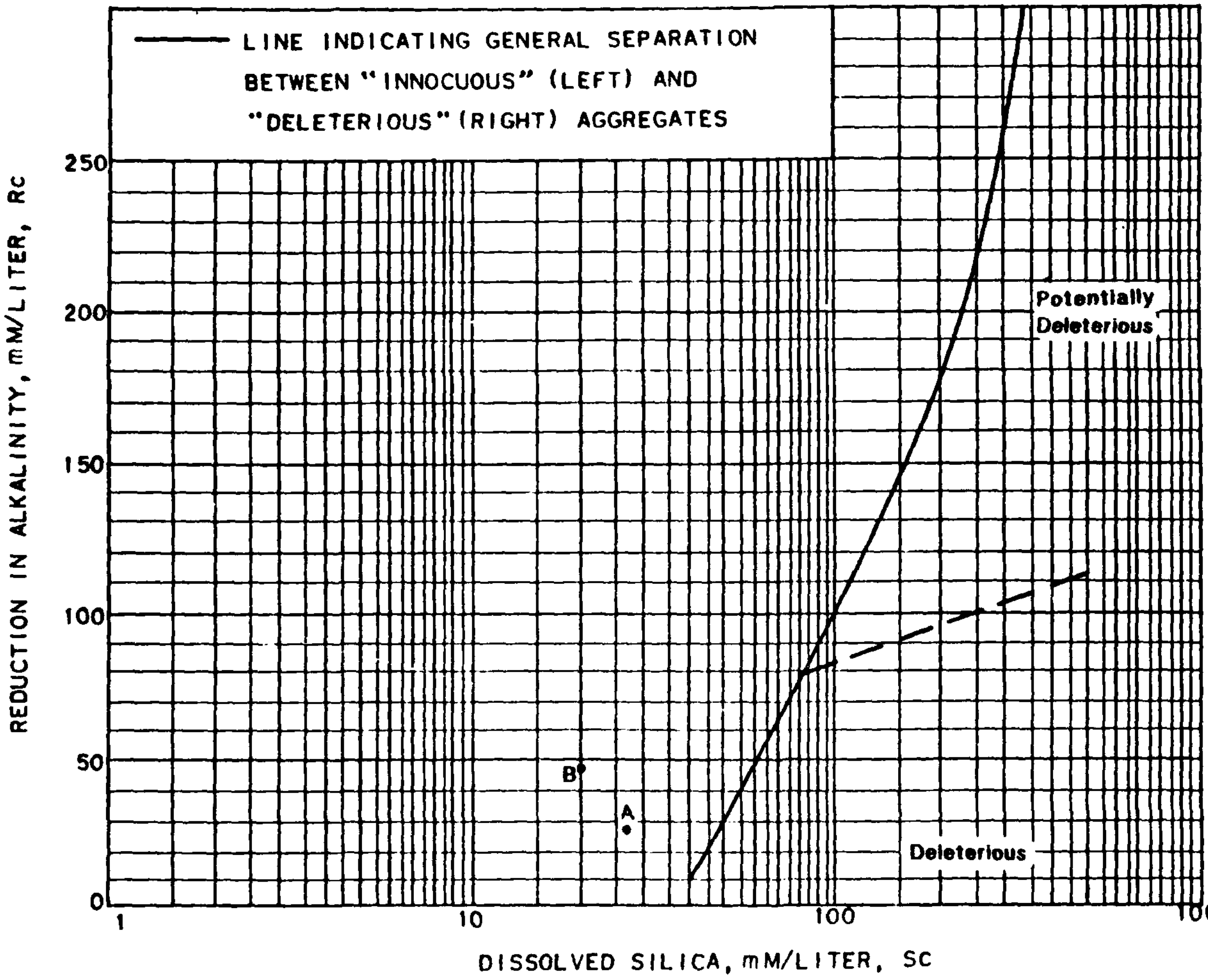
RESULTS OF CHEMICAL TEST FOR REACTIVITY OF AGGREGATE WITH SODIUM HYDROXIDE

DATE: February 1985

WES FORM 896
DEC. '55

FIGURE 2

CORPS OF ENGINEERS, U. S. ARMY, South Pacific DIVISION.



PROJECT: MILL CREEK LEVEE
4th Street Crushers
Fine &Coarse Aggregate
METHOD CRD-C 128

LEGEND

A - Fine aggregate
B - Coarse aggregate

POINT	Sc	Rc
A	27	28
B	20	49

RESULTS OF CHEMICAL TEST FOR REACTIVITY OF AGGREGATE WITH SODIUM HYDROXIDE

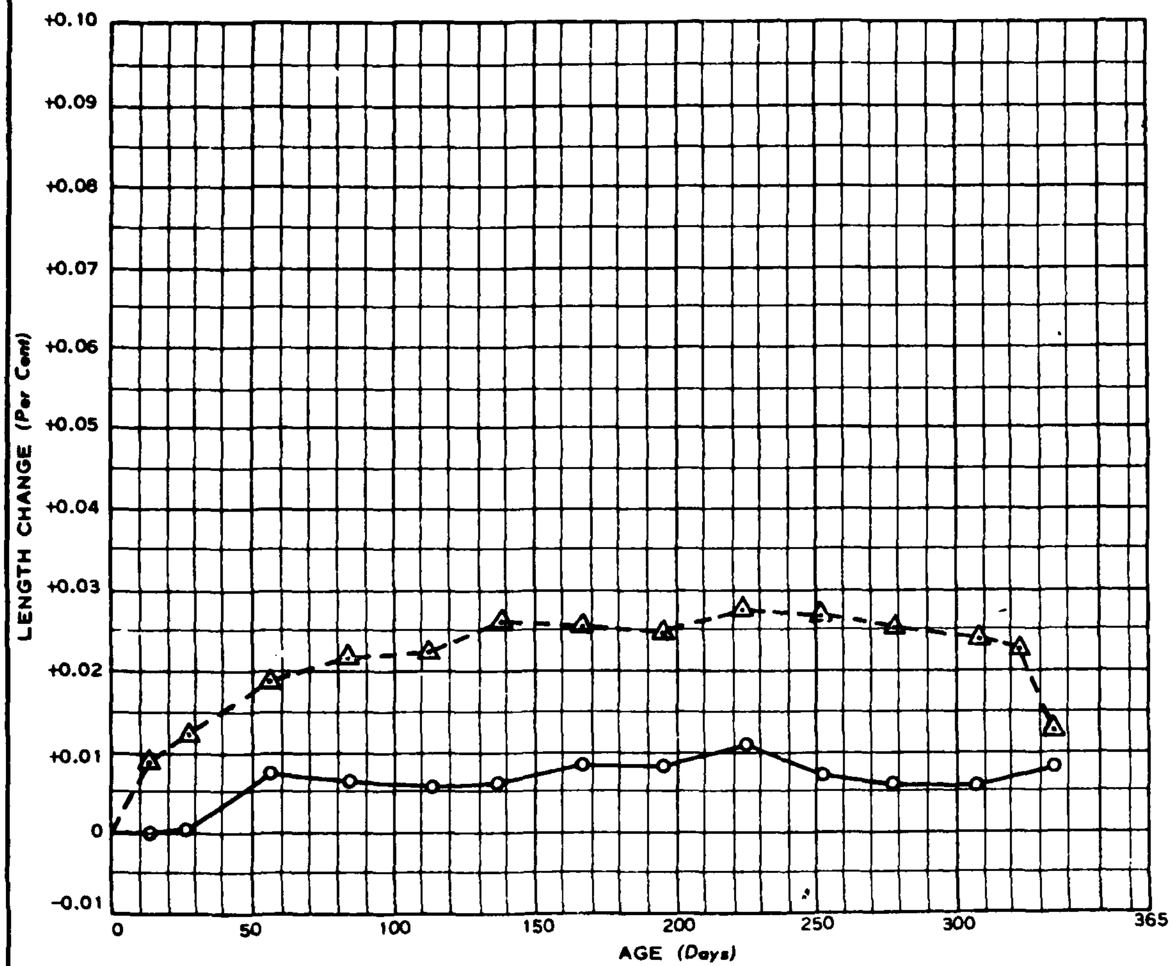
DATE: February 1985

WES FORM 896
DEC. '55

FIGURE 3

FROM: CORPS OF ENGINEERS
U. S. ARMY
South Pacific DIVISION

REACTIVITY OF AGGREGATES WITH ALKALIES



RESULTS OF TEST FOR LENGTH CHANGE DUE TO
CHEMICAL REACTION IN CONCRETE MATERIAL

SYMBOL:

METHOD: CRD-C 123

AGGREGATE

MILL CREEK LEVEE

4th Street Crushers

CEMENT

_______ % Na_2O EQUIVALENT
_______ % Na_2O EQUIVALENT
_______ % Na_2O EQUIVALENT

LEGEND

SYMBOL	COMBINATION
O——O	
Δ- - - -Δ	
□——□	

LENGTH CHANGE

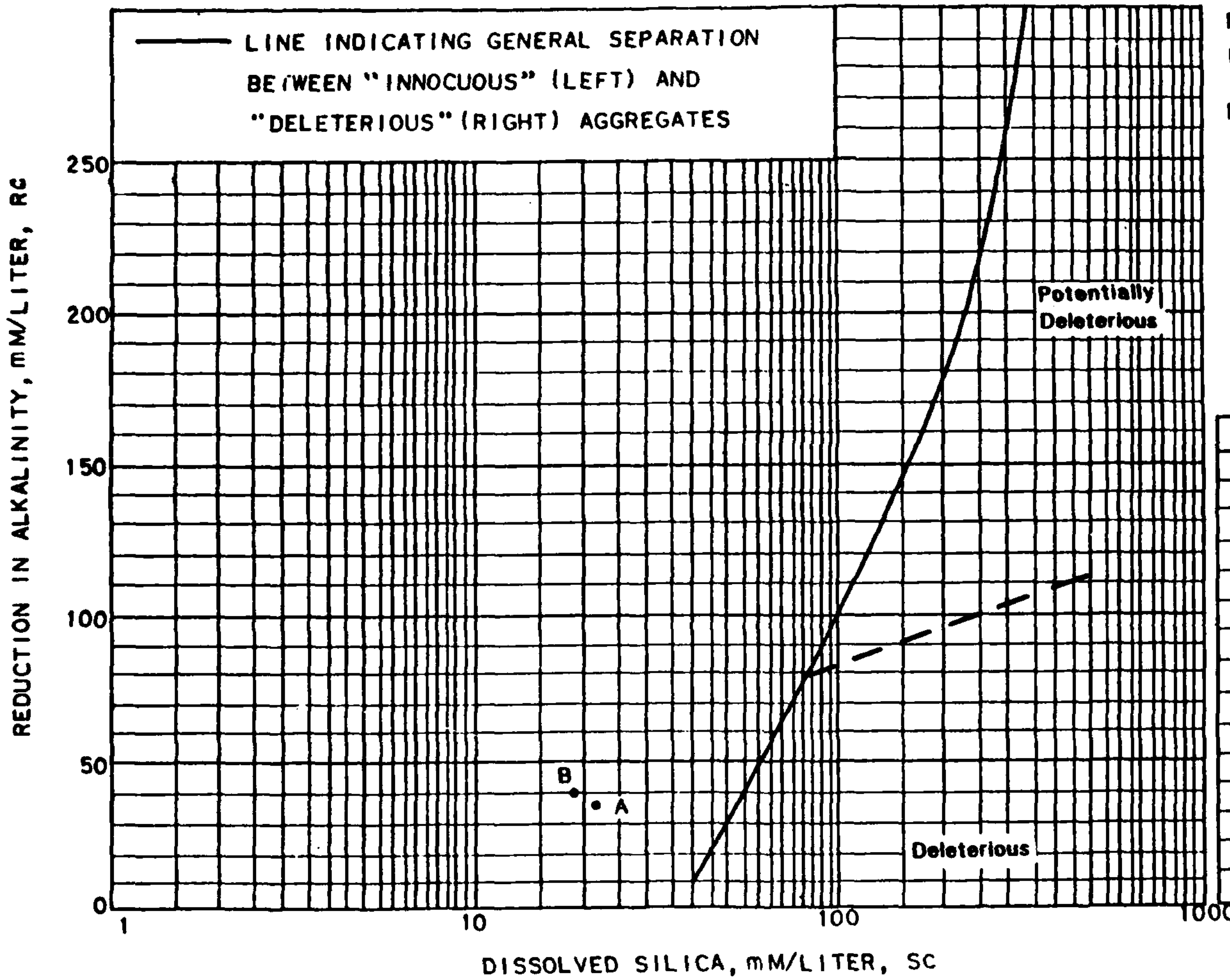
_______ %
_______ %
_______ %

DATE: **January 1986**

FIGURE 4

WES FORM 895
DEC 1955

CORPS OF ENGINEERS, U. S. ARMY, South Pacific DIVISION.



PROJECT: MILL CREEK LEVEE
Beaumont Concrete Co.
Fine & Coarse Aggregate
METHOD CRD-C 128

LEGEND

A - Fine aggregate
B - Coarse aggregate

POINT	Sc	Rc
A	22	36
B	19	40

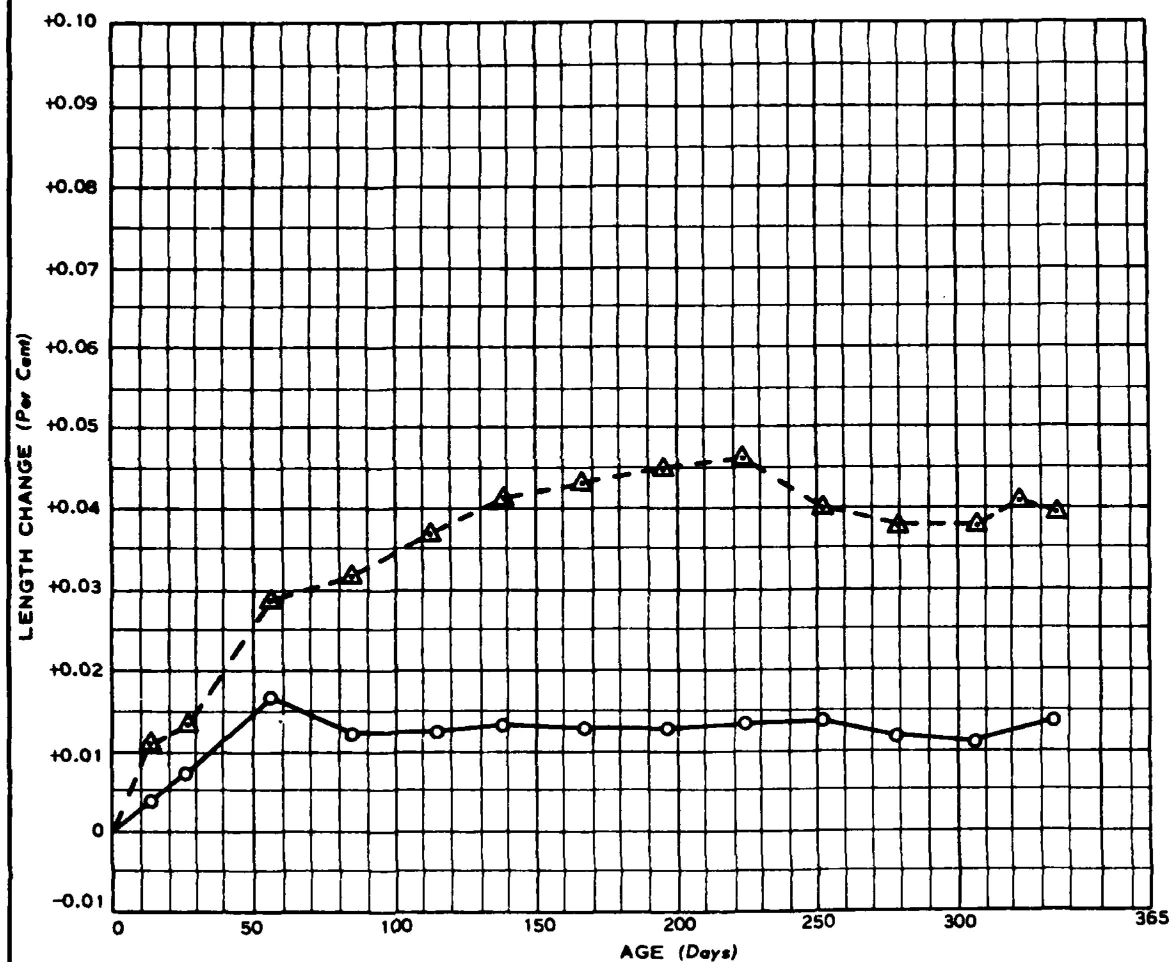
RESULTS OF CHEMICAL TEST FOR REACTIVITY OF AGGREGATE
WITH SODIUM HYDROXIDE

DATE: February 1985

WES FORM
DEC. '55 896

FIGURE 5

REACTIVITY OF AGGREGATES WITH ALKALIES



RESULTS OF TEST FOR LENGTH CHANGE DUE TO CHEMICAL REACTION IN CONCRETE MATERIALS

FROM: CORPS OF ENGINEERS
U. S. ARMY
South Pacific DIVISION

SYMBOL:

METHOD: CRD-C 123

AGGREGATE

MILL CREEK LEVEE

Beaumont Concrete Quarry

CEMENT

_________% Na_2O EQUIVALENT

_________% Na_2O EQUIVALENT

_________% Na_2O EQUIVALENT

LEGEND

SYMBOL	COMBINATION
O———O	
Δ- - - - -Δ	
□———□	

LENGTH CHANGE

_________ %

_________ %

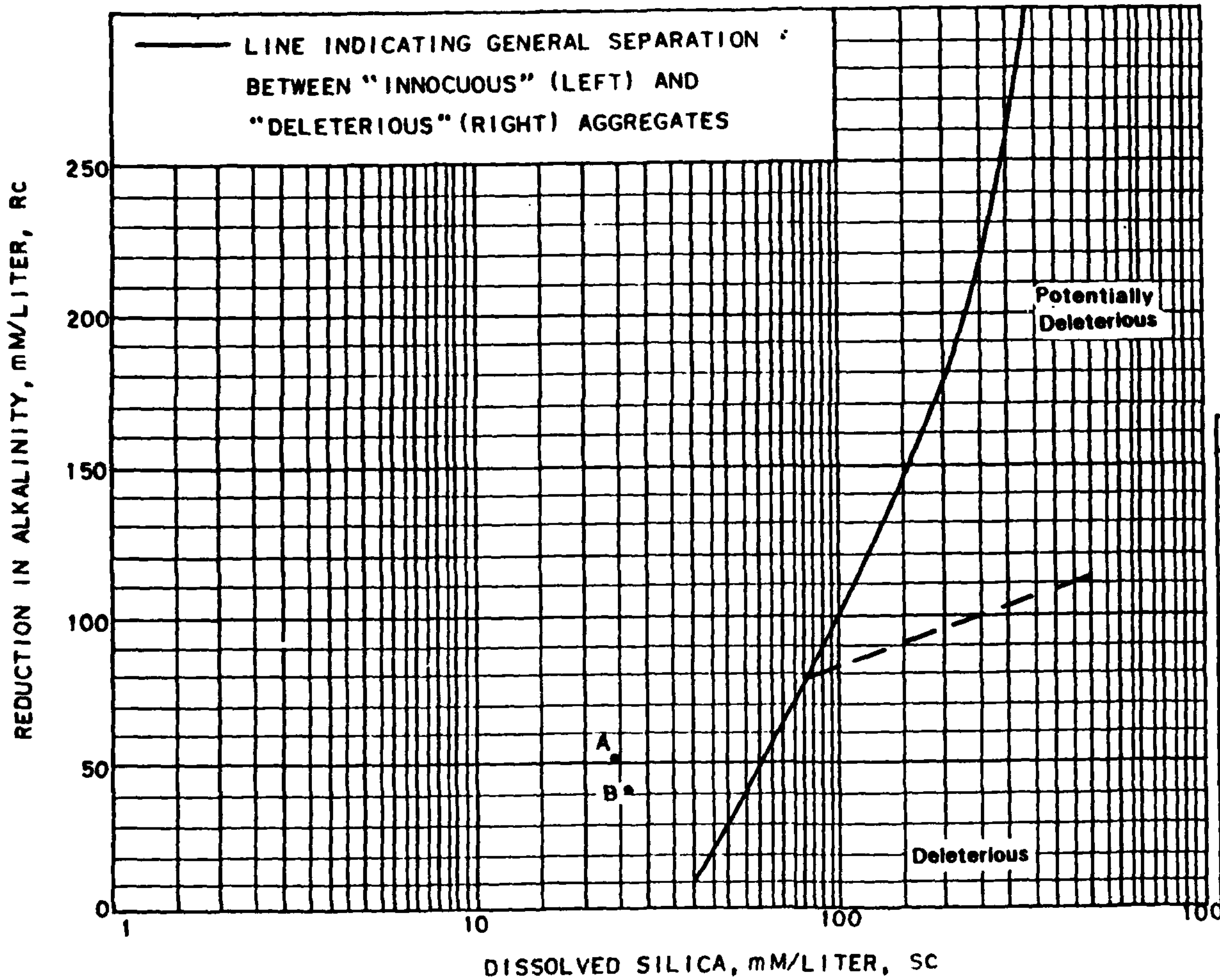
_________ %

DATE: **January 1986**

WES FORM 895
DEC 1955

FIGURE 6

CORPS OF ENGINEERS, U. S. ARMY, South Pacific DIVISION.



PROJECT: MILL CREEK LEVEE
C.L. Pharris
Fine & Coarse Aggregate
METHOD CRD-C 128

LEGEND

A - Fine aggregate
B - Coarse aggregate

POINT	Sc	Rc
A	24	51
B	26	41

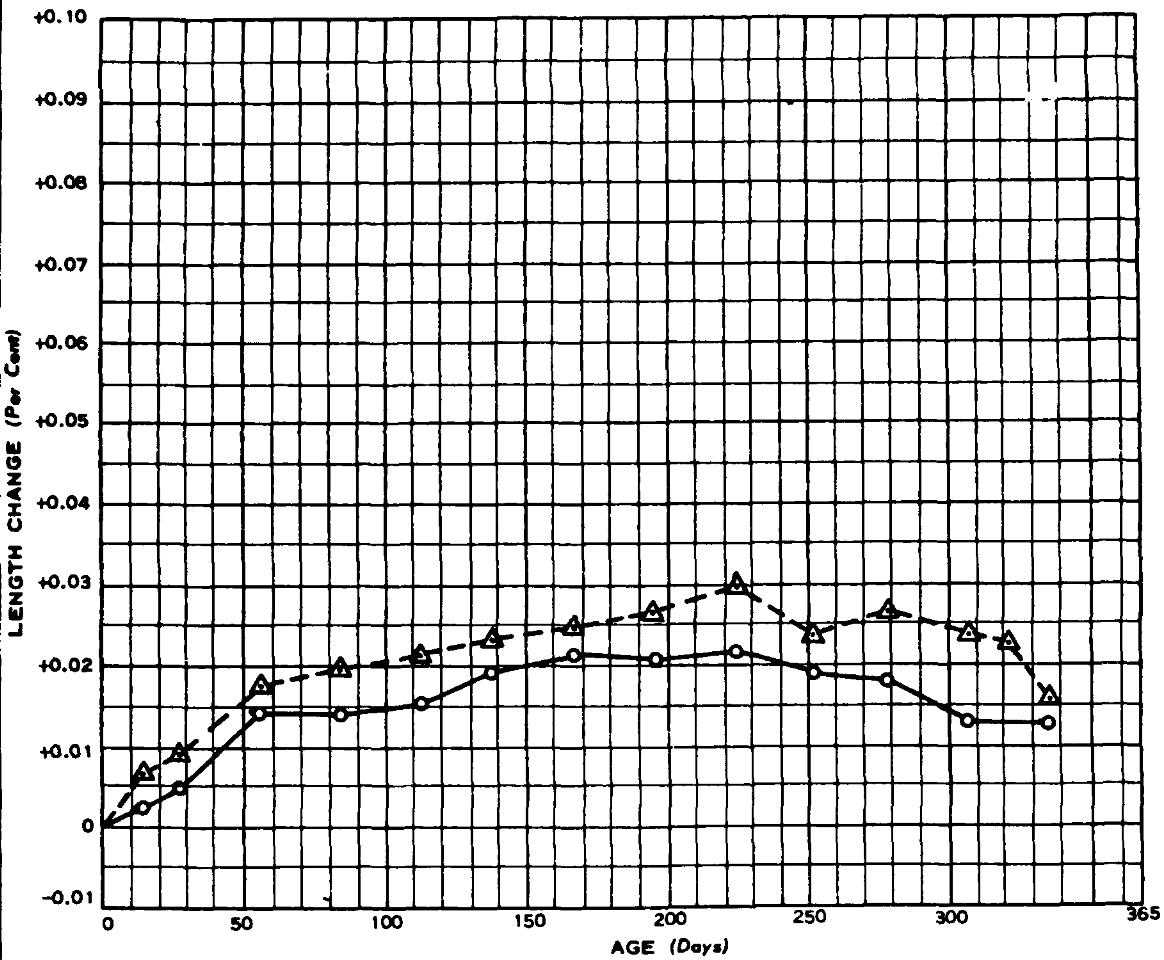
RESULTS OF CHEMICAL TEST FOR REACTIVITY OF AGGREGATE WITH SODIUM HYDROXIDE

DATE: February 1985

WES FORM 896
DEC. '55

FIGURE 7

REACTIVITY OF AGGREGATES WITH ALKALIES



RESULTS OF TEST FOR LENGTH CHANGE DUE TO CHEMICAL REACTION IN CONCRETE MATERIALS

FROM: CORPS OF ENGINEERS
U. S. ARMY
South Pacific DIVISION

SYMBOL:

METHOD: CRD-C 123

AGGREGATE

MILL CREEK LEVEE

C.L. Pharris

CEMENT

________% Na_2O EQUIVALENT

________% Na_2O EQUIVALENT

________% Na_2O EQUIVALENT

LEGEND

SYMBOL	COMBINATION
O———O	
Δ- - - -Δ	
□———□	

LENGTH CHANGE

________%

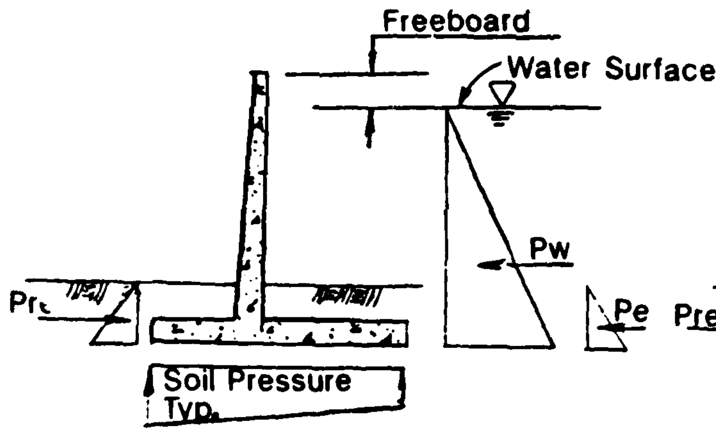
________%

________%

DATE: January 1986

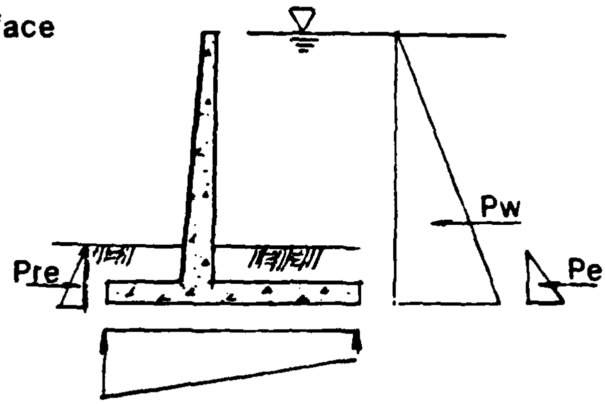
WES FORM 895
DEC 1955

FIGURE 8



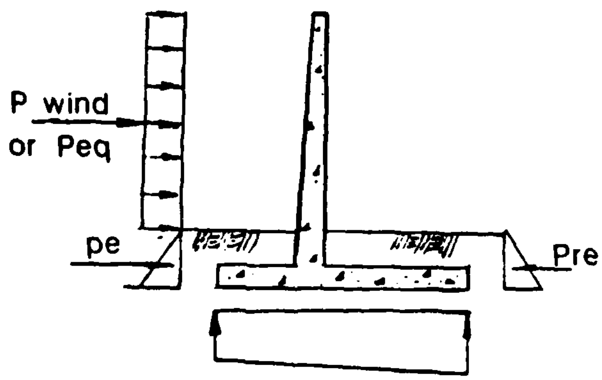
CASE I

Design Water Level



CASE II

Extreme Flood



CASE III

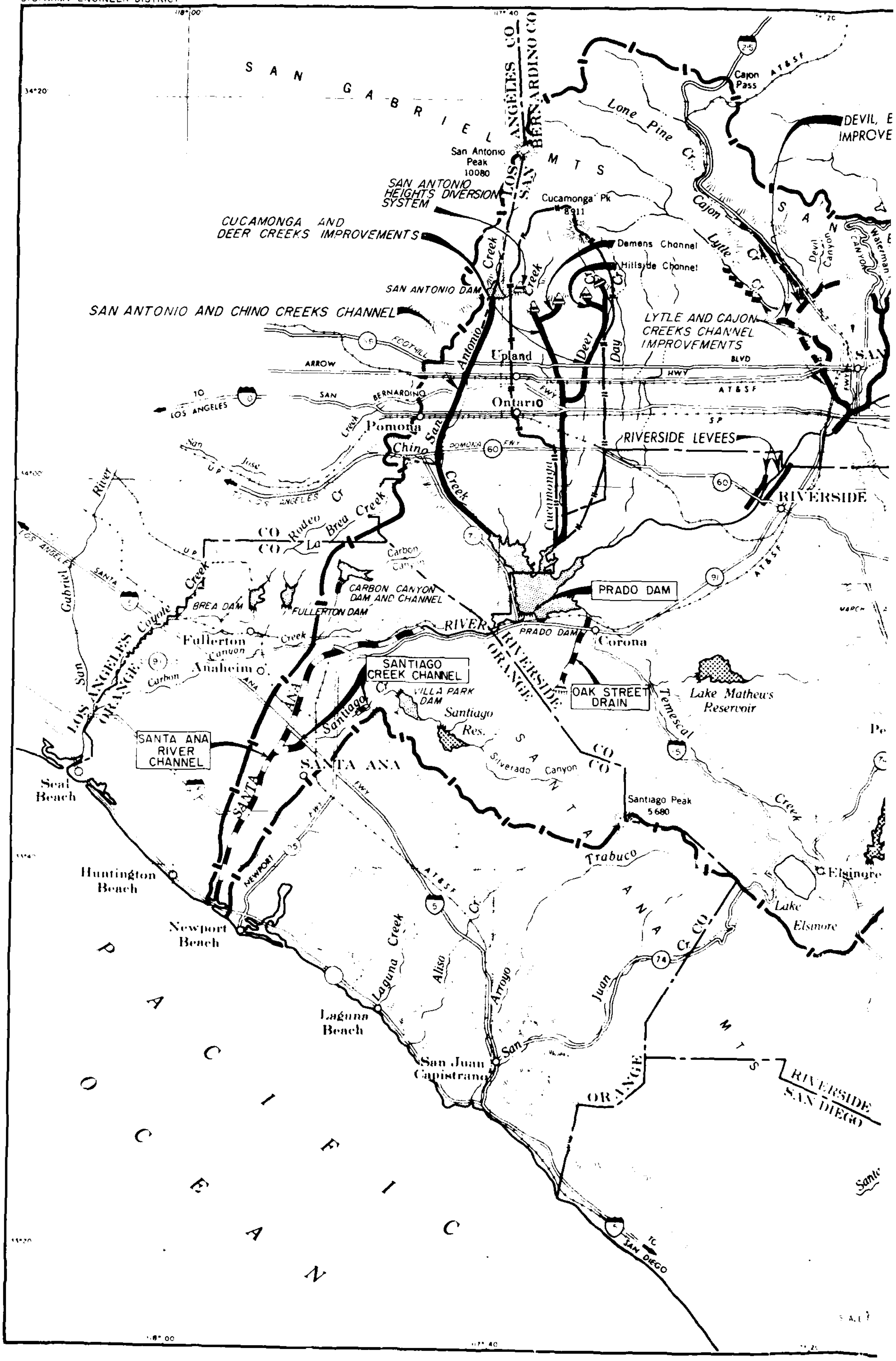
Wind or Seismic Force

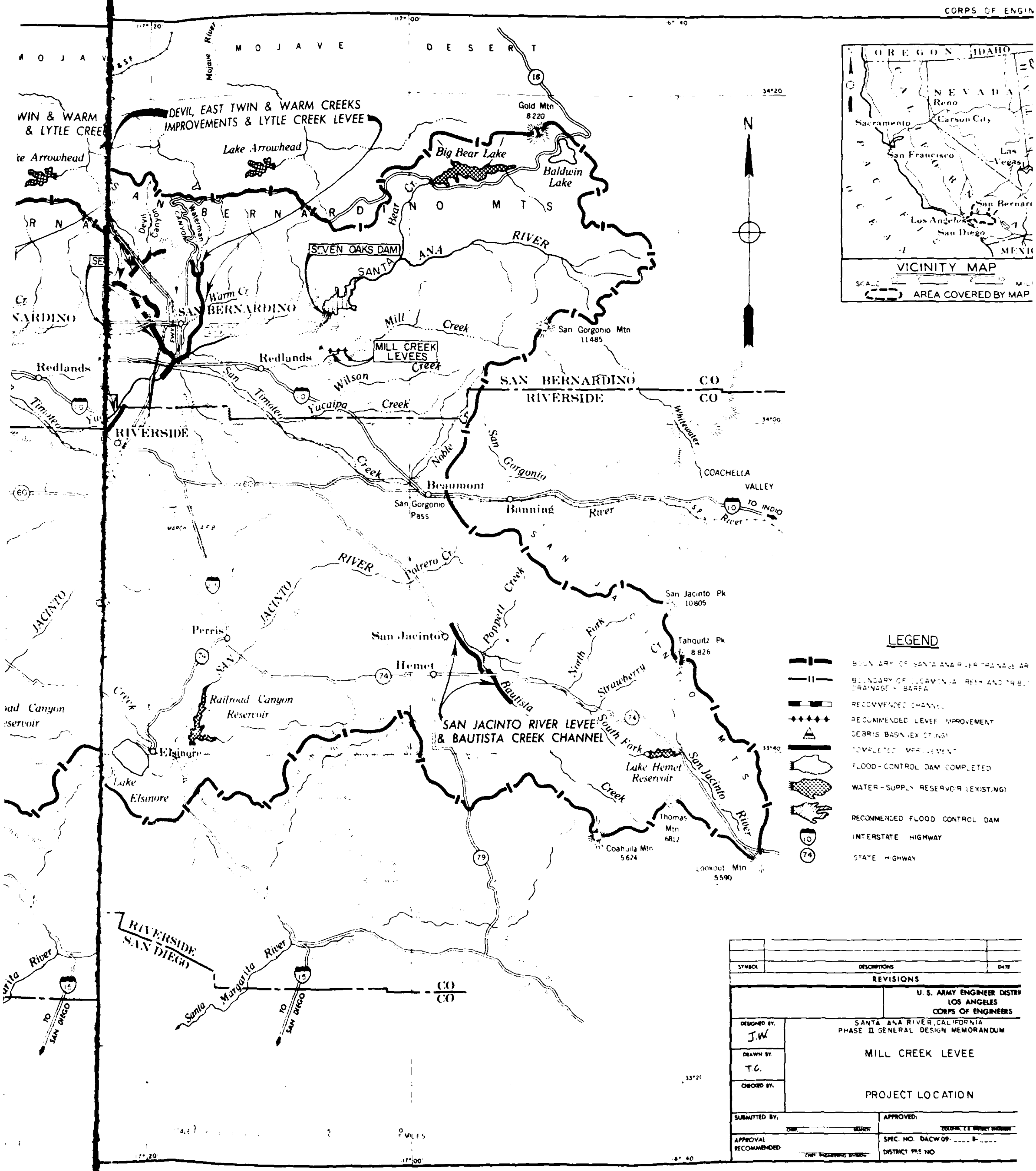
FLOODWALL LOADING CONDITIONS

Note: Loads are unfactored

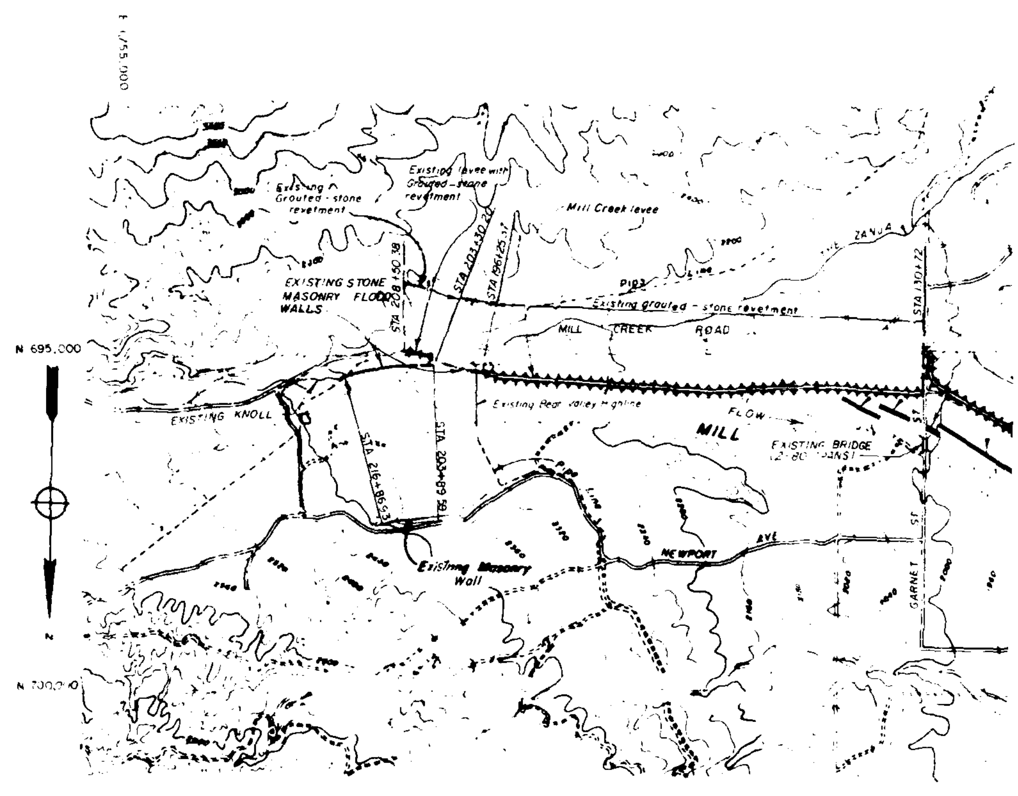
FIGURE 9

U.S. ARMY ENGINEER DISTRICT




CORPS OF ENGIN
MOJAVE DESERT
DEVIL, EAST TWIN & WARM CREEKS IMPROVEMENTS & LYTLE CREEK LEVEE
Gold Mtn 8220
Lake Arrowhead
Big Bear Lake
Baldwin Lake
SAN BERNARDINO MTS
SEVEN OAKS DAM
SANTA ANA RIVER
Bear Cr.
Devil Canyon
Waterman Canyon
Warm Cr.
SAN BERNARDINO
Mill Creek
MILL CREEK LEVEES
San Gorgonio Mtn 11485
Redlands
Wilson Creek
San Timoteo Creek
Yucaipa Creek
SAN BERNARDINO CO
RIVERSIDE CO
RIVERSIDE
Noble Cr.
San Gorgonio
Whitewater
COACHELLA VALLEY
Beaumont
San Gorgonio Pass
Banning
River
TO INDIO
SAN JACINTO
RIVER
Potrero Cr.
Poppett Creek
San Jacinto Pk 10805
Tahquitz Pk 8826
Perris
San Jacinto
Hemet
North Fork
Strawberry Cr.
Bautista
Railroad Canyon Reservoir
SAN JACINTO RIVER LEVEE & BAUTISTA CREEK CHANNEL
South Fork
Lake Hemet Reservoir
San Jacinto River
SAN JACINTO MTS
Elsinore
Lake Elsinore
Creek
Thomas Mtn 6812
Coahuila Mtn 5624
Lookout Mtn 5590
RIVERSIDE
SAN DIEGO
Santa Margarita River
CO
CO
TO SAN DIEGO
OREGON
IDAHO
NEVADA
Reno
Sacramento
Carson City
San Francisco
Las Vegas
San Bernardino
Los Angeles
San Diego
MEXICO
VICINITY MAP
AREA COVERED BY MAP
LEGEND
BOUNDARY OF SANTA ANA RIVER DRAINAGE AREA
RECOMMENDED CHANNEL
RECOMMENDED LEVEE IMPROVEMENT
DEBRIS BASIN (EXISTING)
COMPLETED IMPROVEMENT
FLOOD-CONTROL DAM COMPLETED
WATER-SUPPLY RESERVOIR (EXISTING)
RECOMMENDED FLOOD CONTROL DAM
INTERSTATE HIGHWAY
STATE HIGHWAY
SYMBOL
DESCRIPTIONS
DATE
REVISIONS
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS
SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM
MILL CREEK LEVEE
PROJECT LOCATION
DESIGNED BY. J.W.
DRAWN BY. T.C.
CHECKED BY.
SUBMITTED BY.
APPROVED:
APPROVAL RECOMMENDED
SPEC. NO. DACW09-
DISTRICT FILE NO

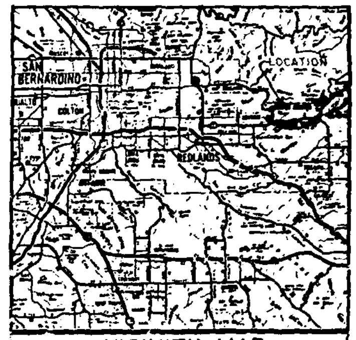
ENVIRONMENTAL
ENHANCEMENT
THRU ENGINEERING



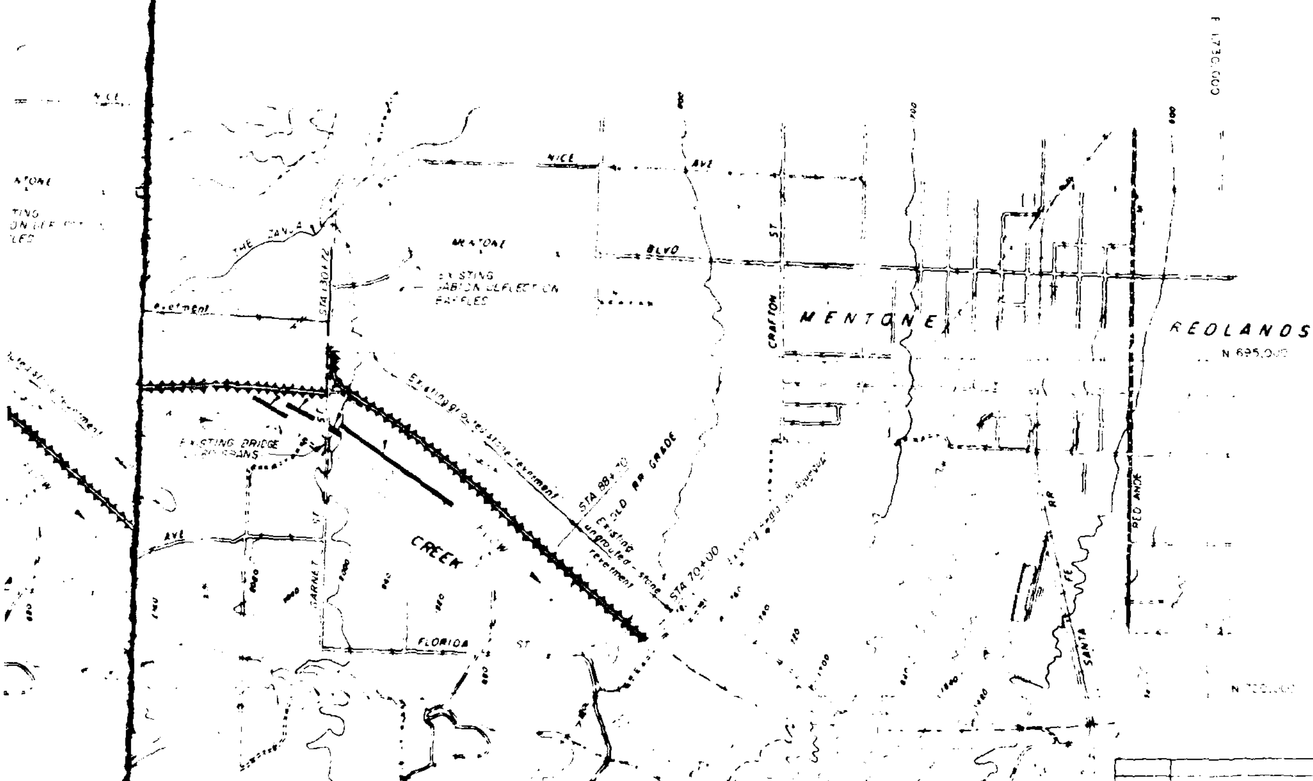
PLAN

SCALE

E 1,755,000



VICINITY MAP



PLAN

SCALE 1 IN = 1000 FT

1000 0 1000 2000 3000

SYMBOL	DESCRIPTIONS	DATE	APPR

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: H. T

DRAWN BY:

CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE

VICINITY MAP AND PLAN

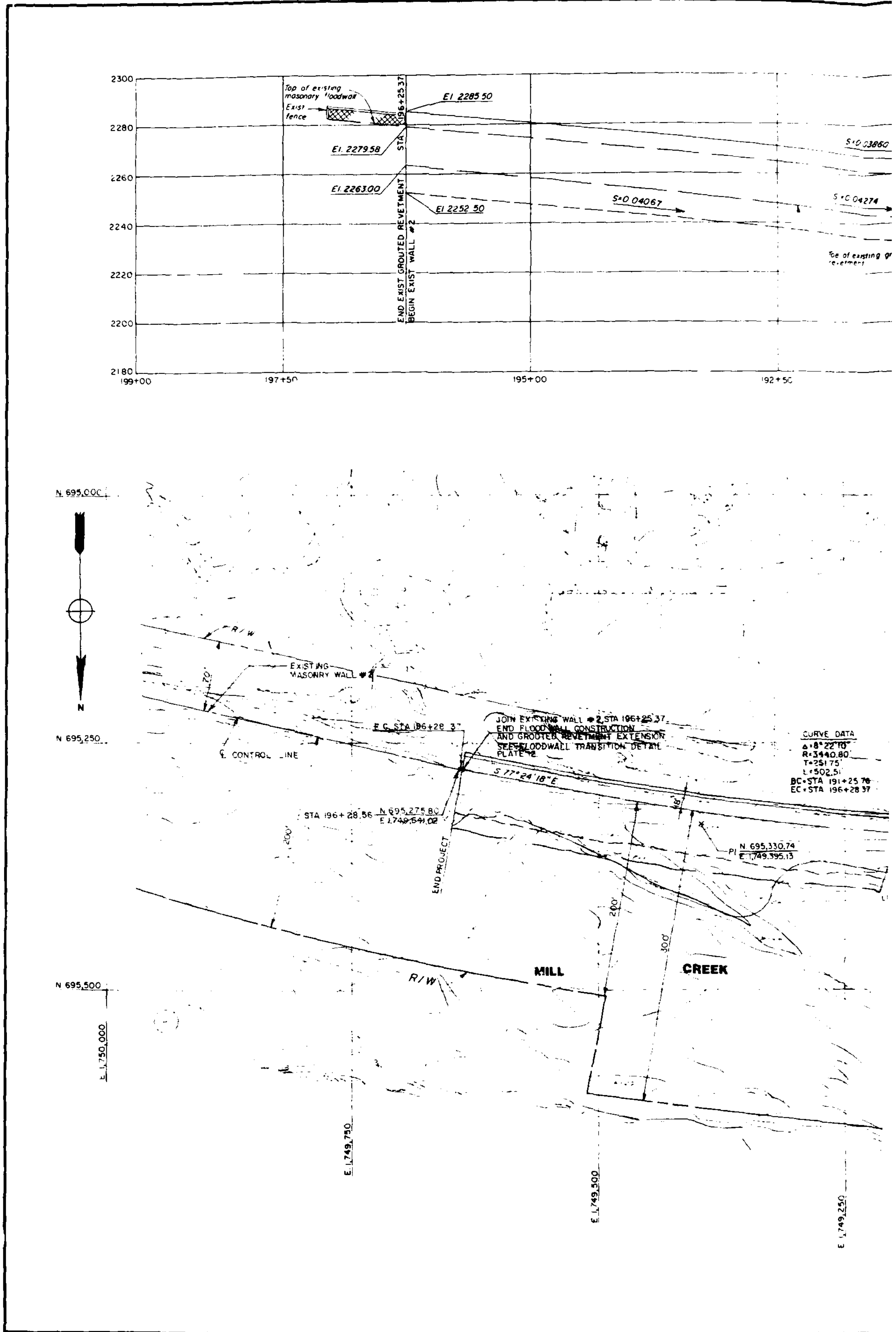
SUBMITTED BY

DATE APPROVED

SPEC NO DACW09- ___ -B- ____

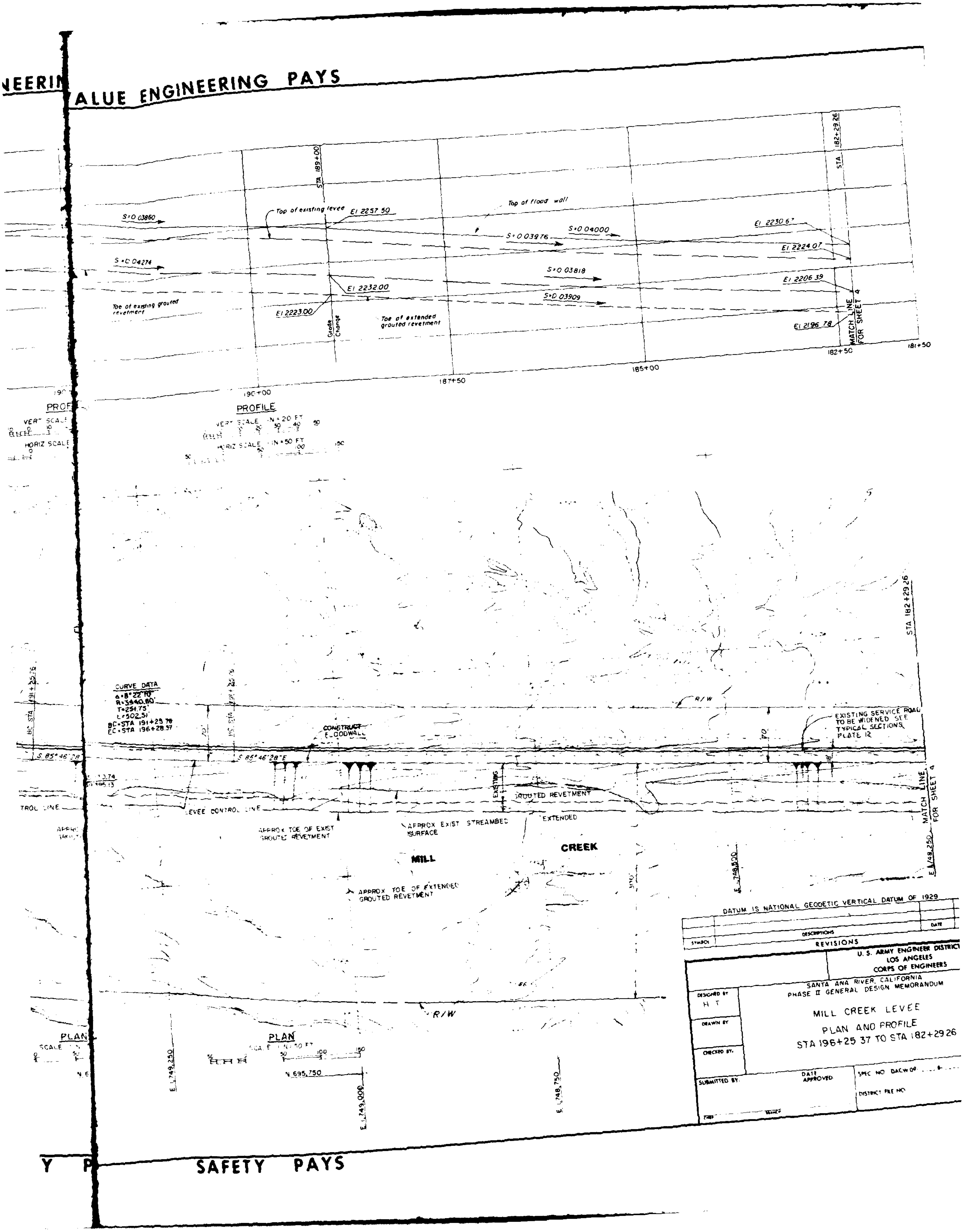
DISTRICT FILE NO

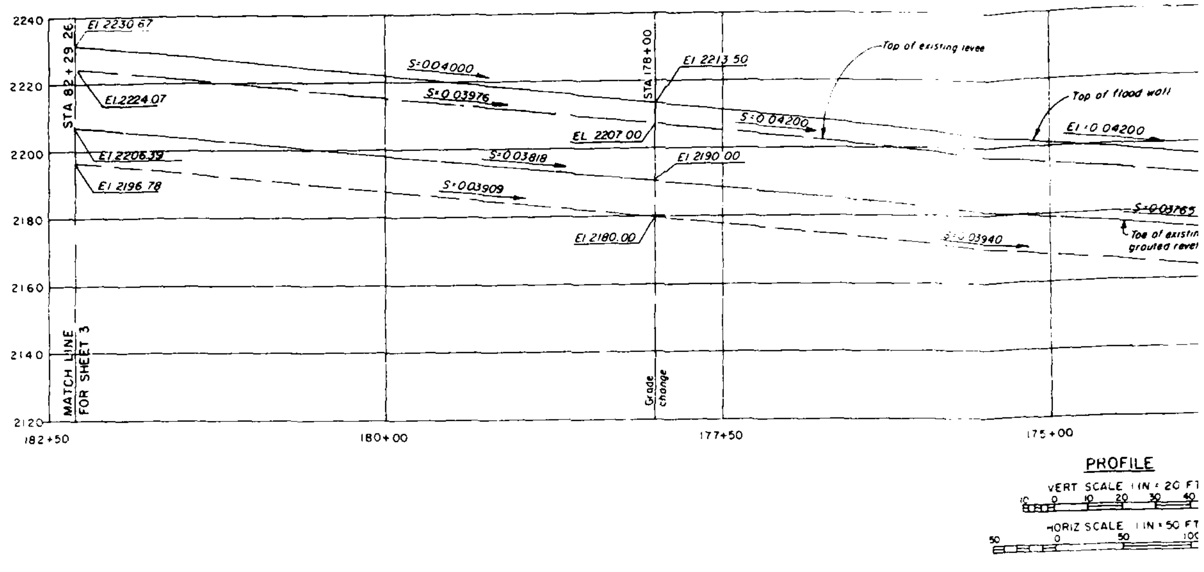
VALUE E

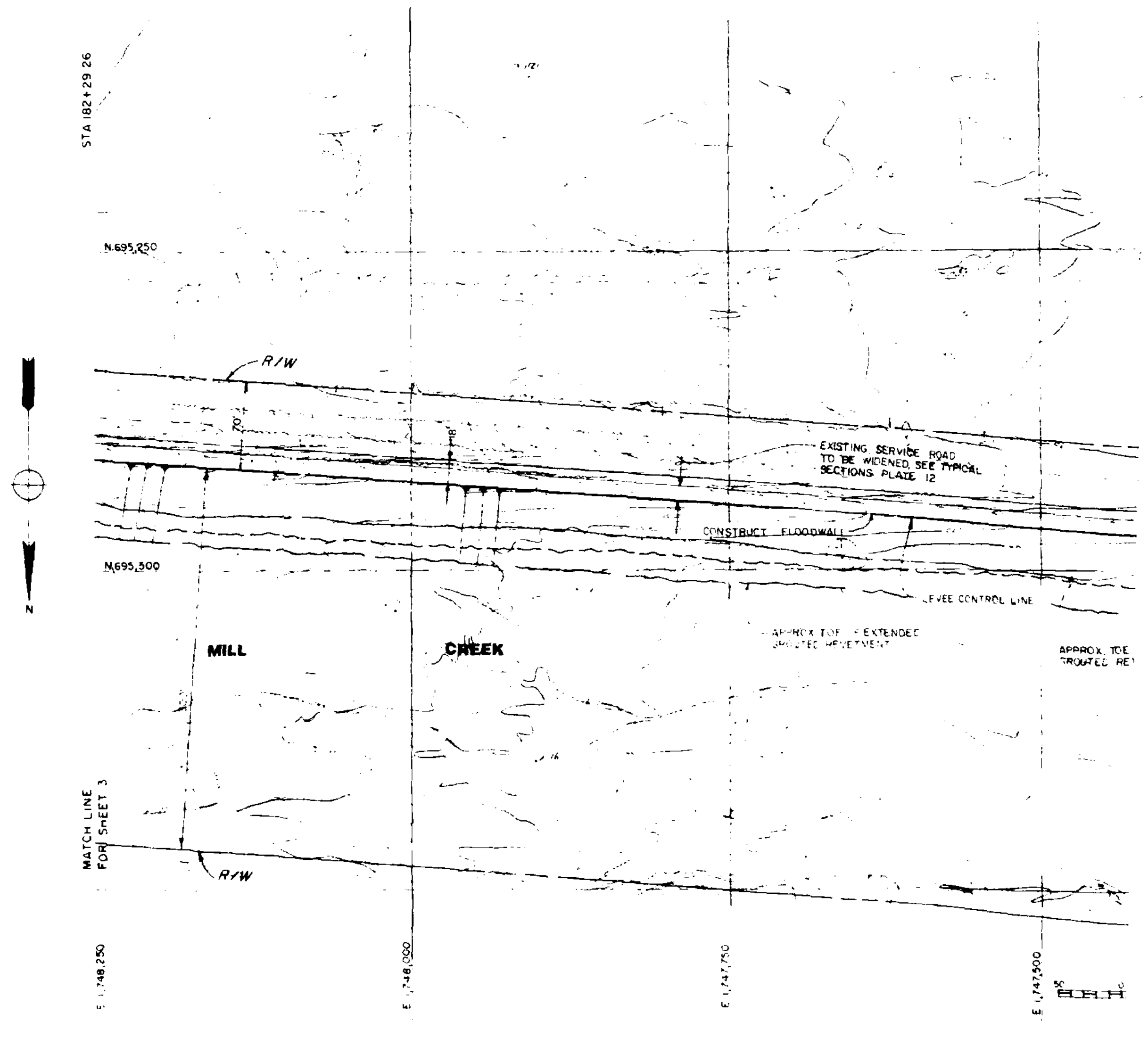


ENVIRONMENTAL
ENHANCEMENT
THRU ENGINEERING

S

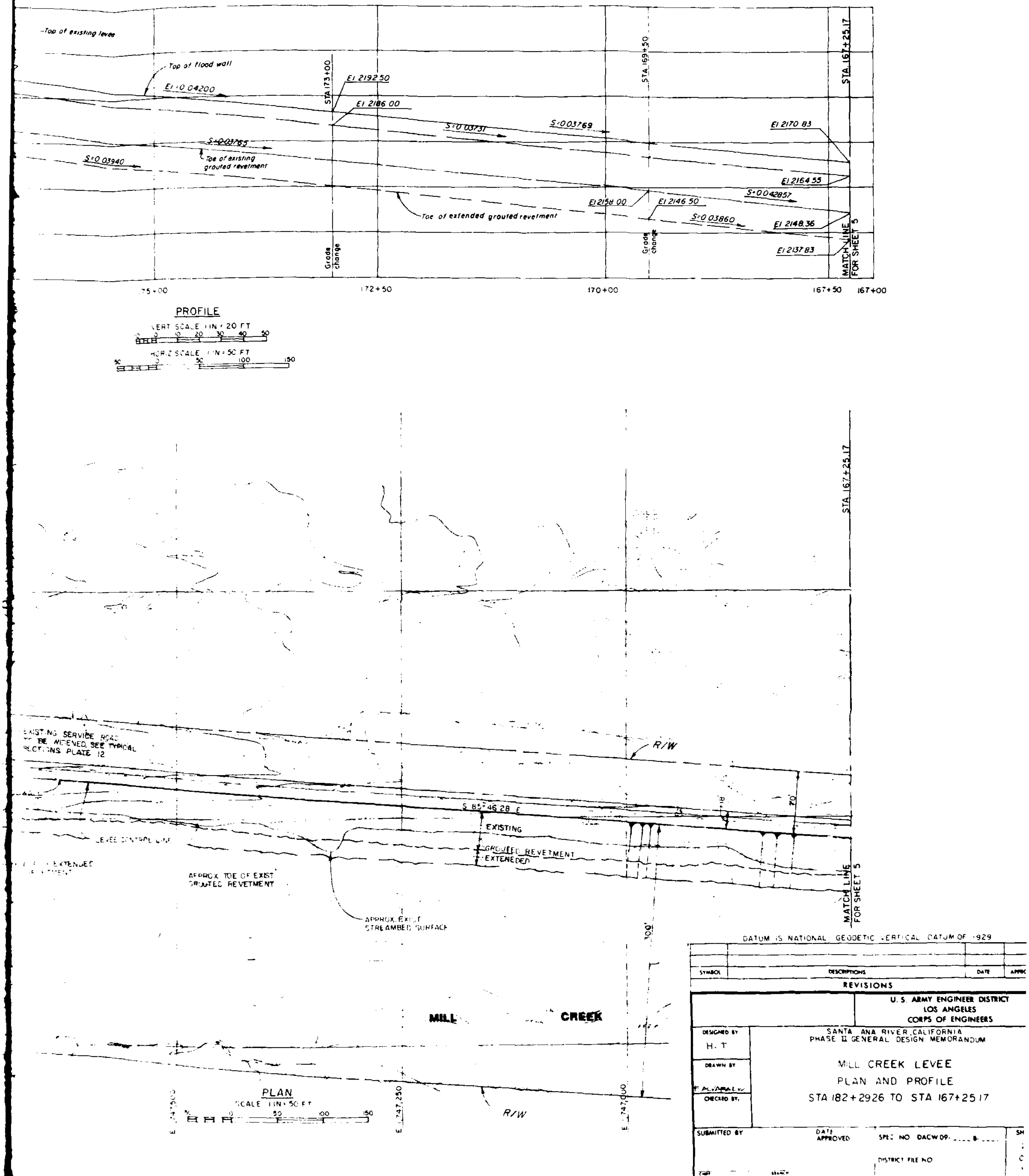

VALUE ENGINEERING PAYS
STA 189+00
STA 182+29.26
Top of existing levee
El 2257.50
Top of flood wall
S=0.03860
S=0.03976
S=0.04000
El 2230.67
El 2224.07
S=0.04274
S=0.03818
El 2206.39
El 2232.00
S=0.03909
Toe of existing grouted revetment
El 2223.00
Grade Change
Toe of extended grouted revetment
El 2196.78
MATCH LINE FOR SHEET 4
190+00
187+50
185+00
182+50
181+50
PROFILE
VERT SCALE 1 IN = 20 FT
HORIZ SCALE 1 IN = 50 FT
CURVE DATA
Δ=8°22'10"
R=3440.80'
T=251.75'
L=502.51'
BC=STA 191+25.78
EC=STA 196+28.37
BC STA 191+25.78
CONSTRUCT E-CODWALL
S 85°46'28"E
R/W
EXISTING SERVICE ROAD TO BE WIDENED SEE TYPICAL SECTIONS PLATE 12
70'
EXISTING
GROUTED REVETMENT
EXTENDED
LEVEE CONTROL LINE
APPROX TOE OF EXIST GROUTED REVETMENT
APPROX EXIST STREAMBED SURFACE
MILL
CREEK
APPROX TOE OF EXTENDED GROUTED REVETMENT
E 1,748,500
E 1,748,250
STA 182+29.26
MATCH LINE FOR SHEET 4
PLAN
SCALE 1 IN = 50 FT
N 695,750
E 1,749,250
E 1,749,000
E 1,748,750
DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929
SYMBOL
DESCRIPTIONS
DATE
REVISIONS
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS
SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM
DESIGNED BY
H T
DRAWN BY
CHECKED BY
MILL CREEK LEVEE
PLAN AND PROFILE
STA 196+25.37 TO STA 182+29.26
SUBMITTED BY
DATE APPROVED
SPEC NO DACW09
DISTRICT FILE NO
SAFETY PAYS





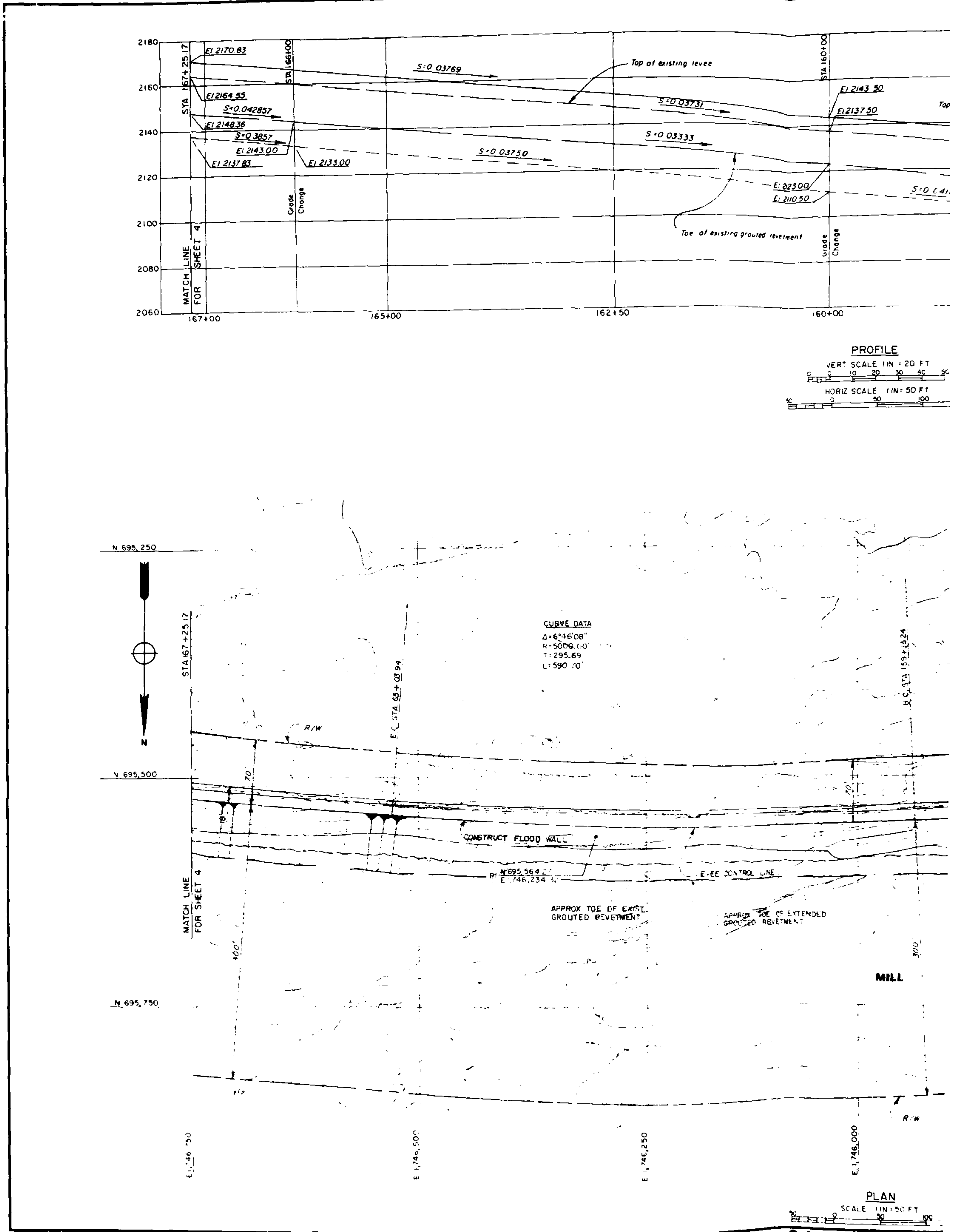
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

VALUE ENGINEERING PAYS

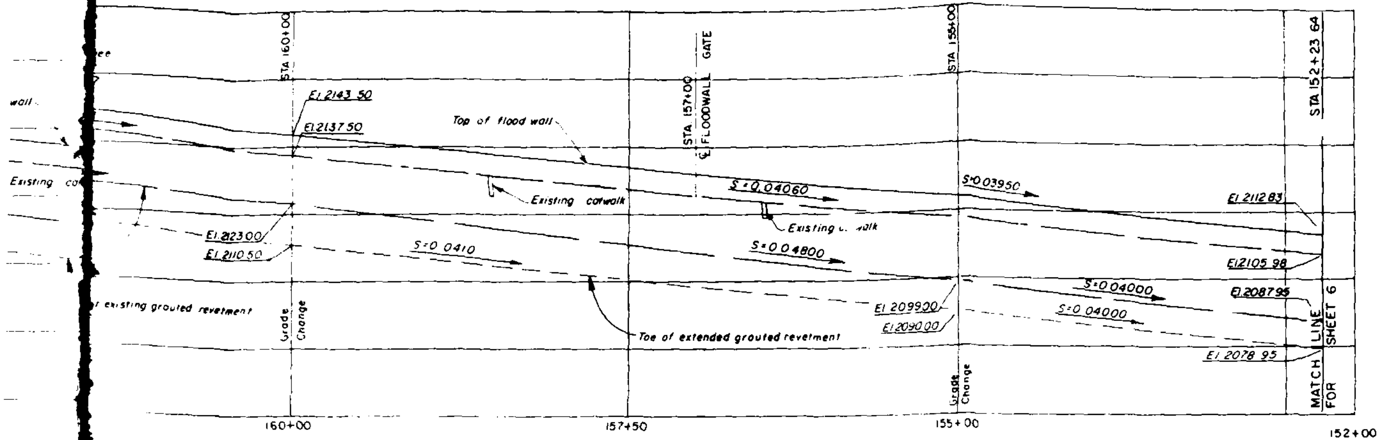


SAFETY PAYS

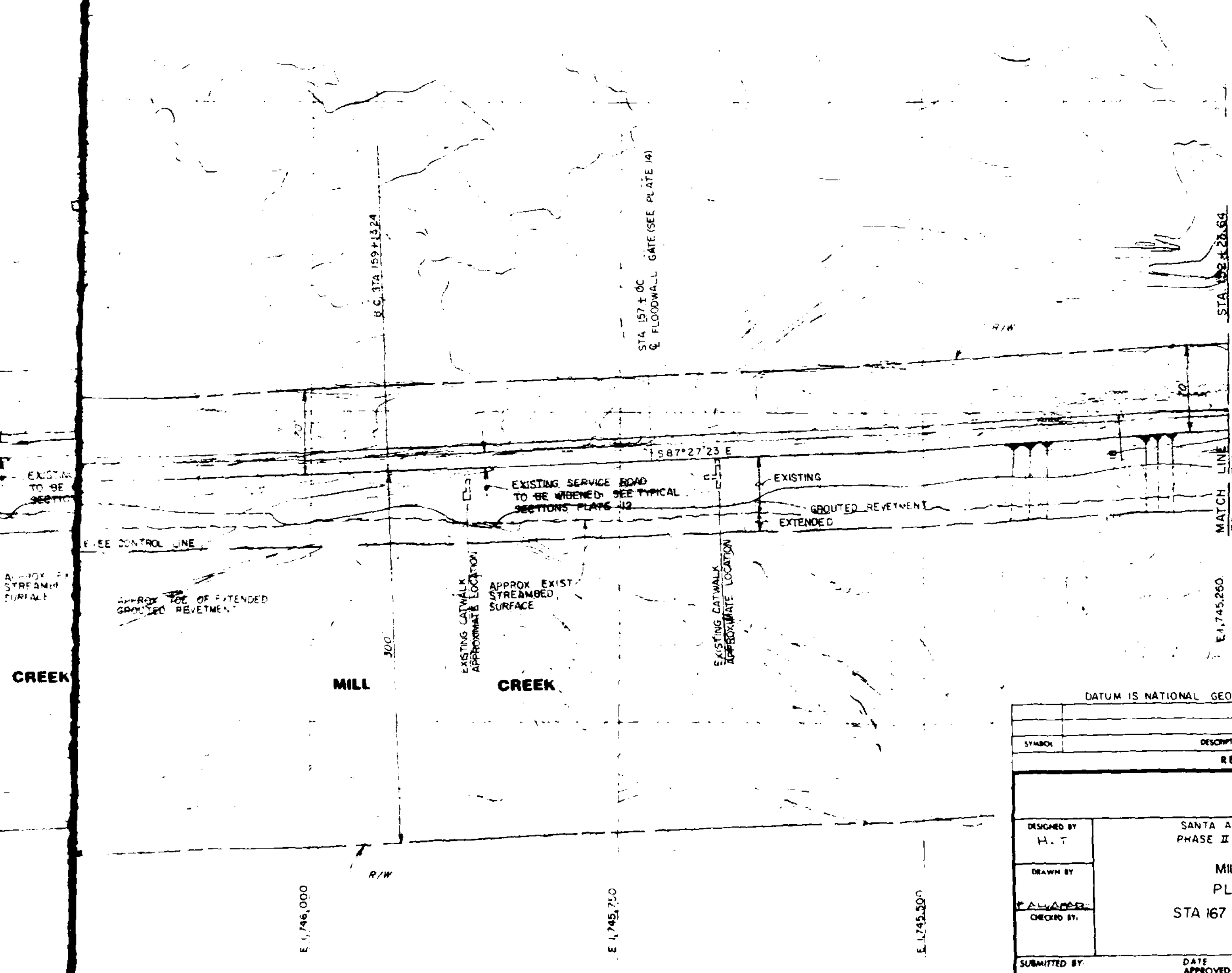
ENVIRONMENTAL
ENHANCEMENT
THRU ENGINEERING



SAFETY PA



PROFILE
VERT SCALE 1 IN = 20 FT
HORIZ SCALE 1 IN = 50 FT



PLAN
SCALE 1 IN = 50 FT

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

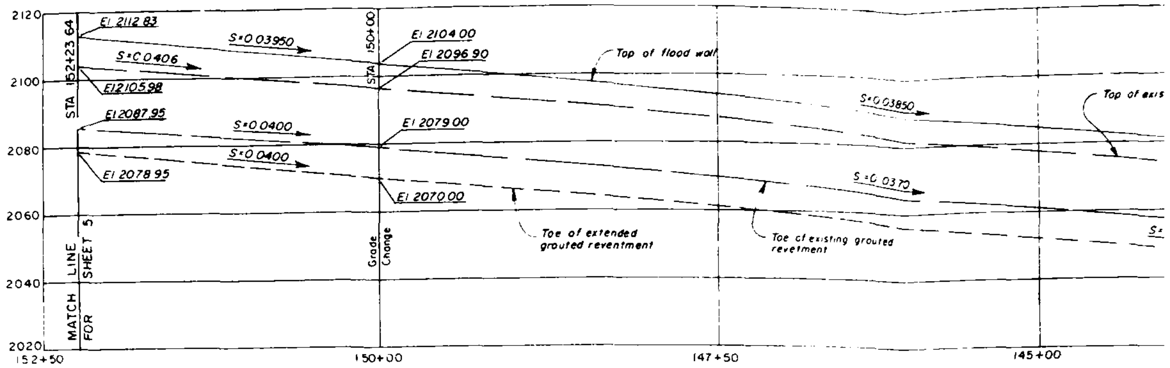
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: H. T.
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE
PLAN AND PROFILE
STA 167+25.17 TO STA 152+23.64

SUBMITTED BY:
DATE APPROVED
SPEC NO DACW09-
DISTRICT FILE NO
SHEET
PLATE

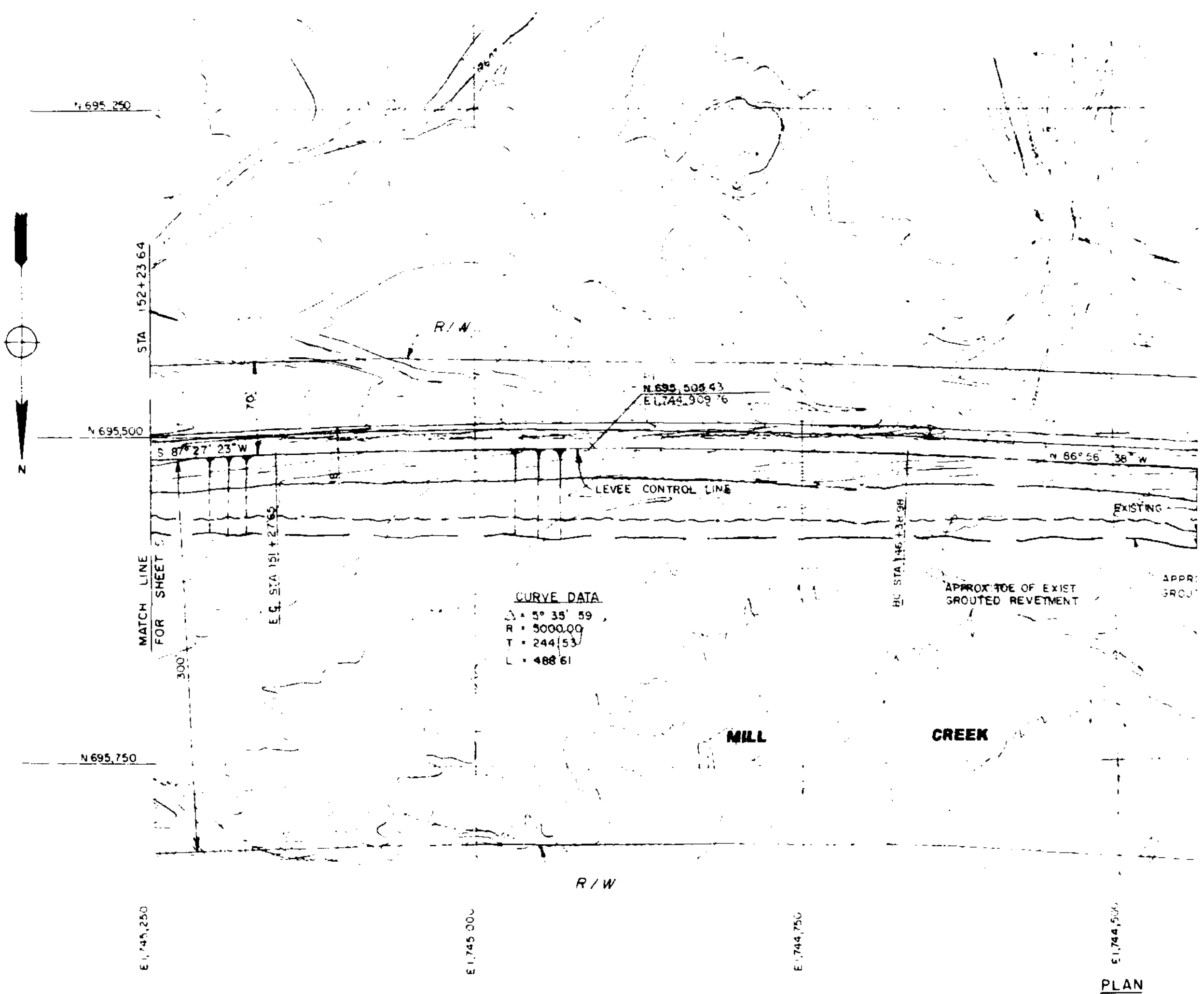


PROFILE

VERT SCALE 1 IN = 20

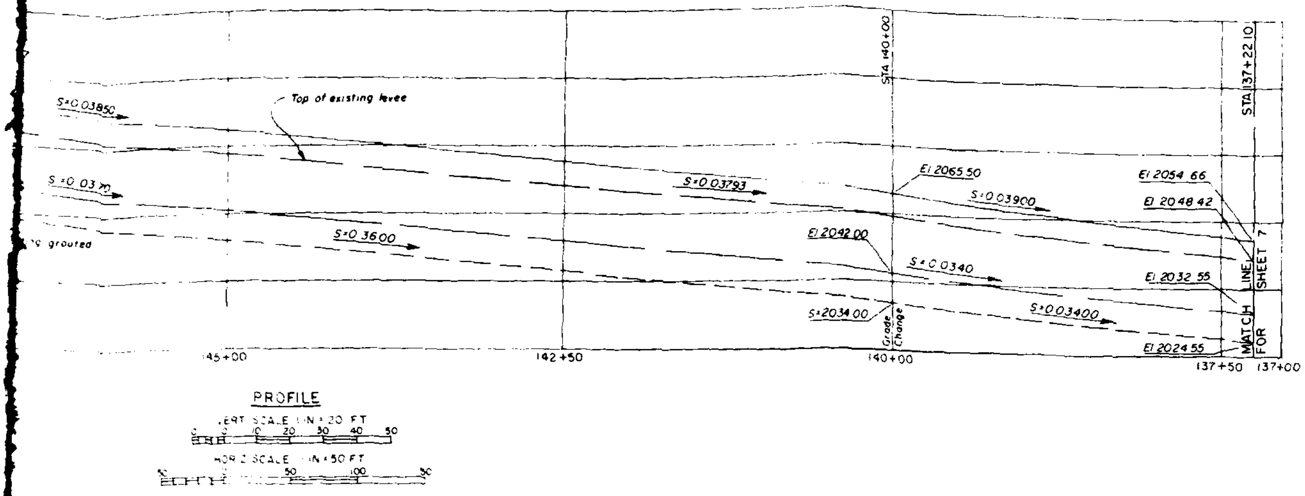
HORIZ SCALE 1 IN = 50

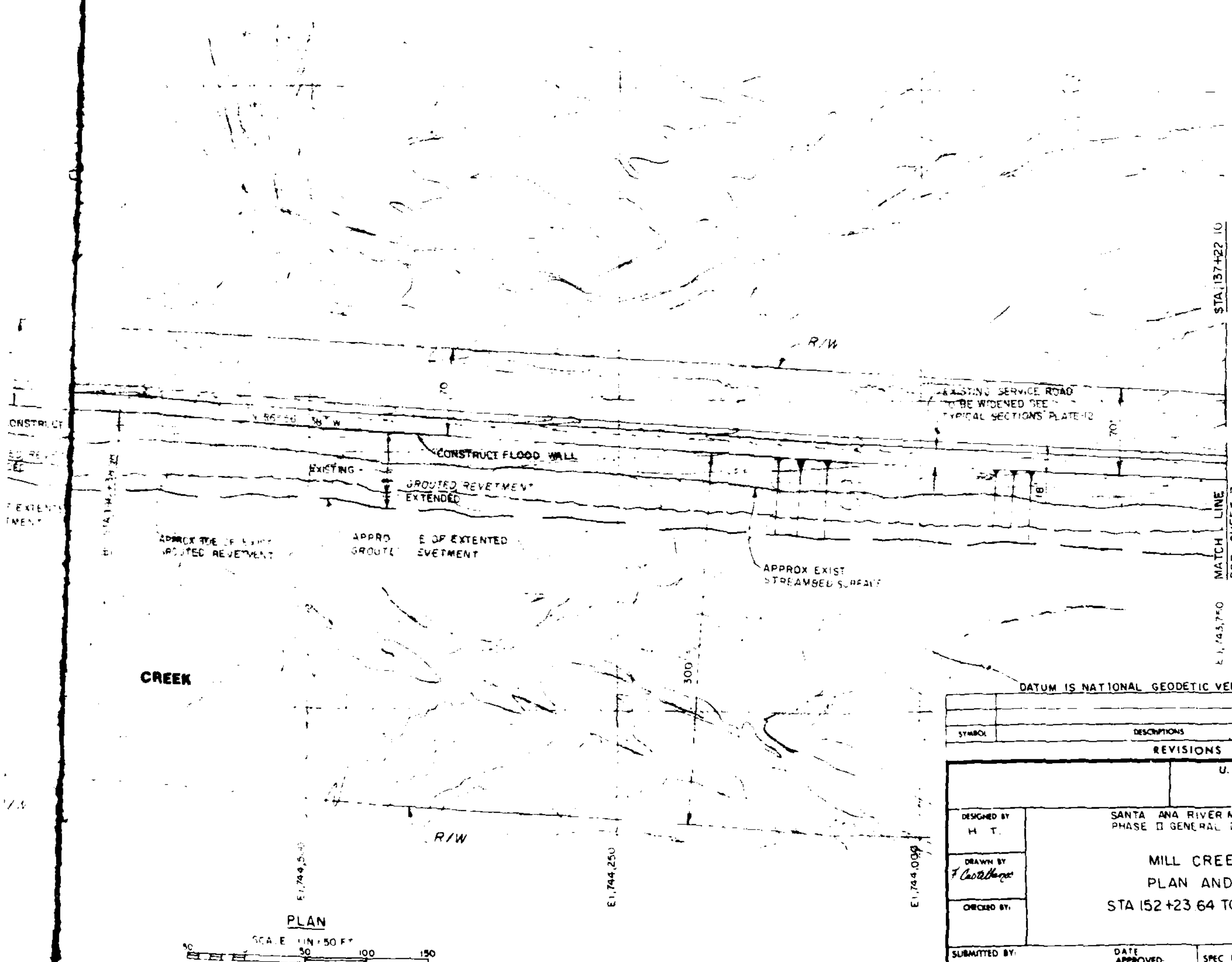
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



PLAN

SCALE 1 IN = 50 FT





DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: H. T.
DRAWN BY: F. Castellanos
CHECKED BY:

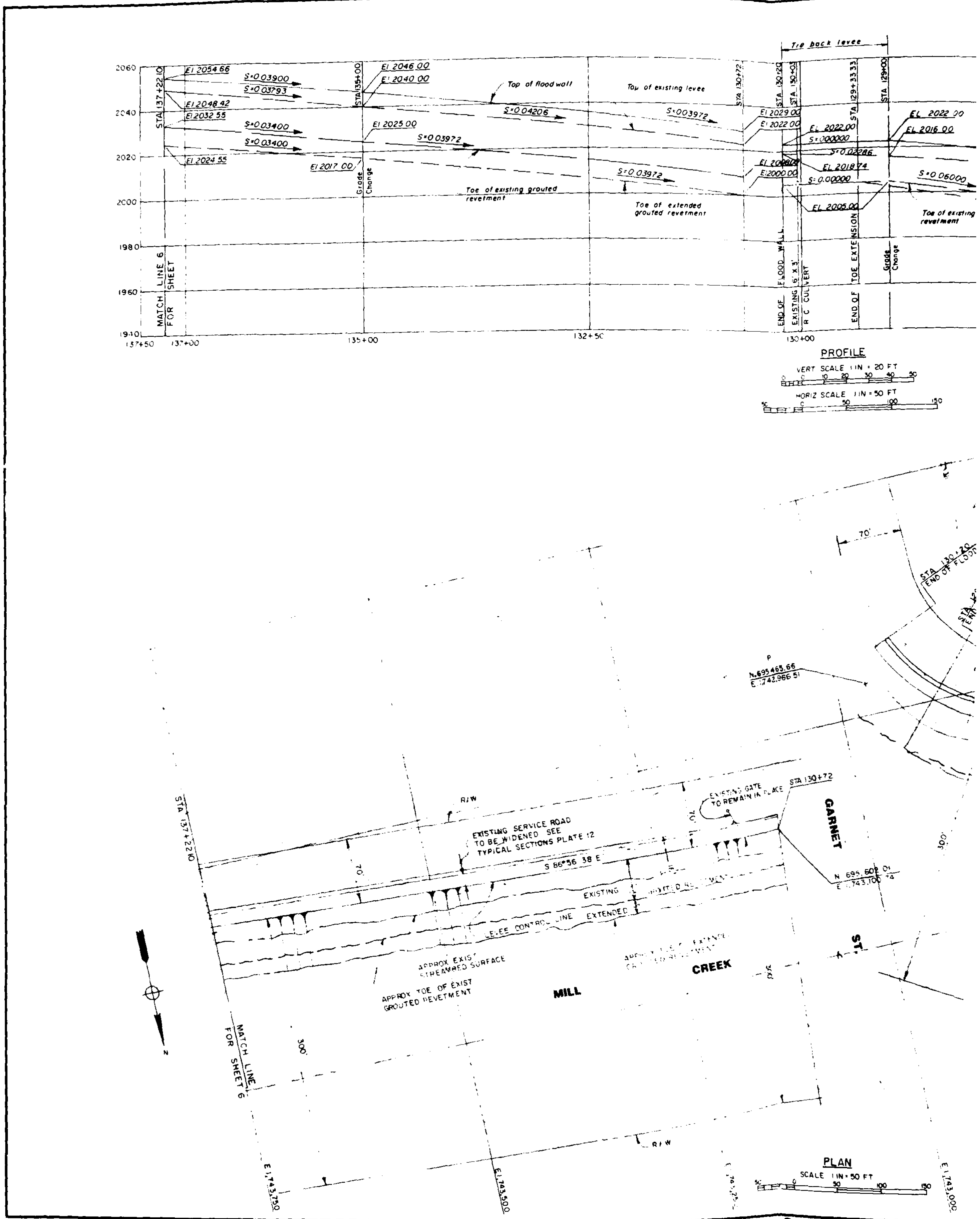
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE
PLAN AND PROFILE
STA 152+23.64 TO STA 137+22.10

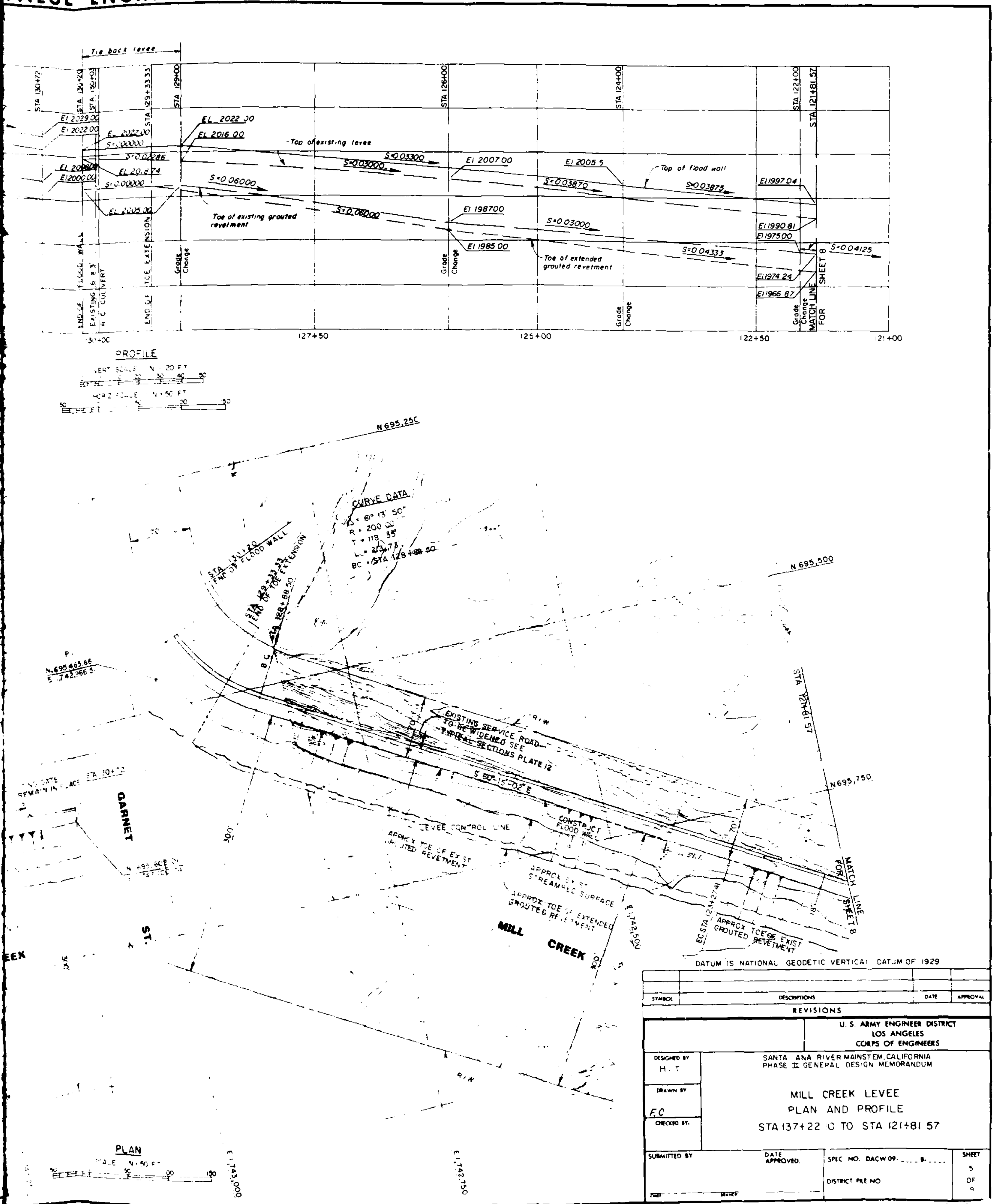
SUBMITTED BY:
DATE APPROVED:
SPEC NO DACW09-__-B-____
DISTRICT FILE NO
SHEET 4 OF 9

CHIEF ____ BRANCH

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

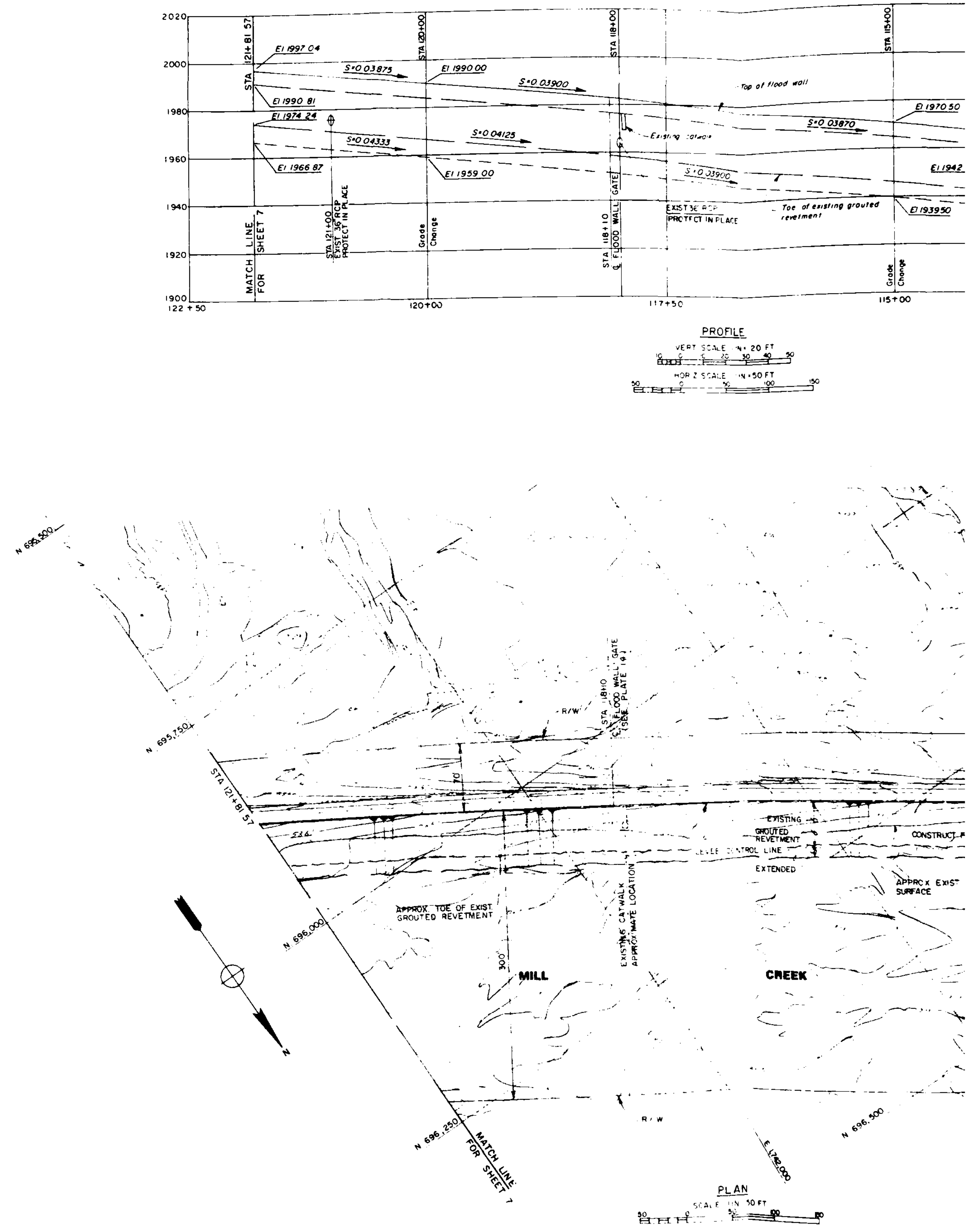


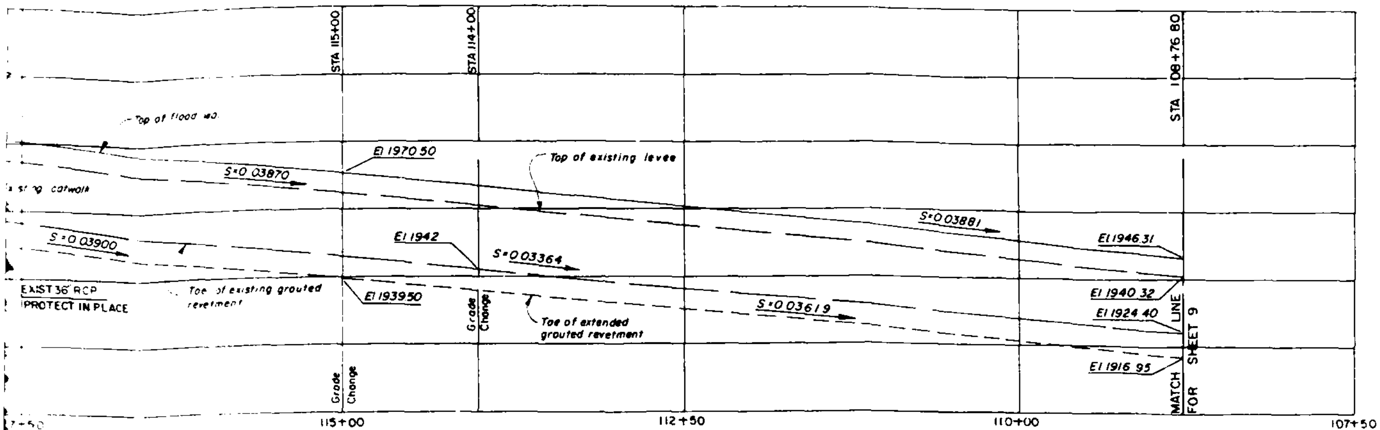
VALUE ENGINEERING PAYS



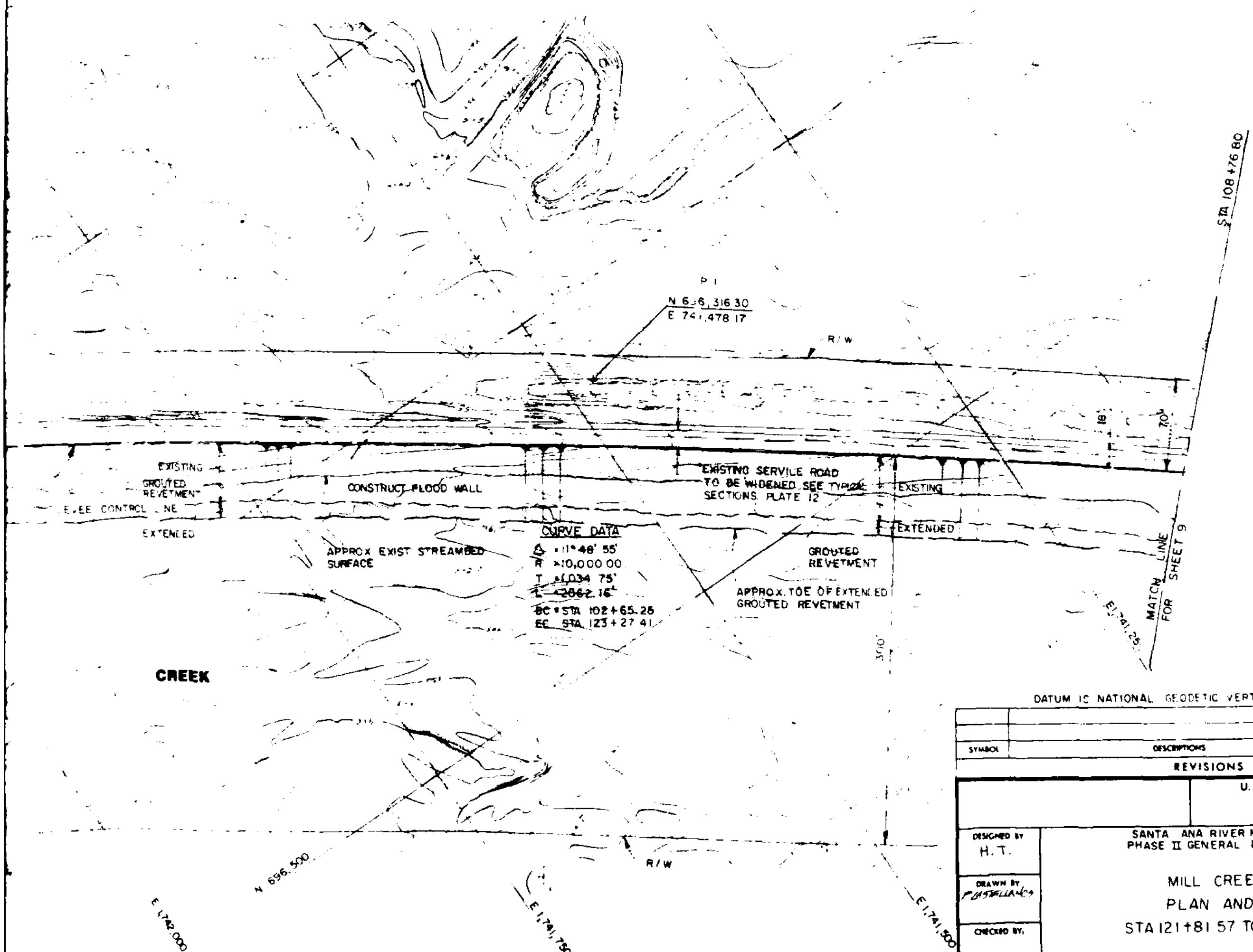
SAFETY PAYS

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING





PROFILE
VERT SCALE 1 IN = 20 FT
HORIZ SCALE 1 IN = 50 FT



PLAN
SCALE 1 IN = 50 FT

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

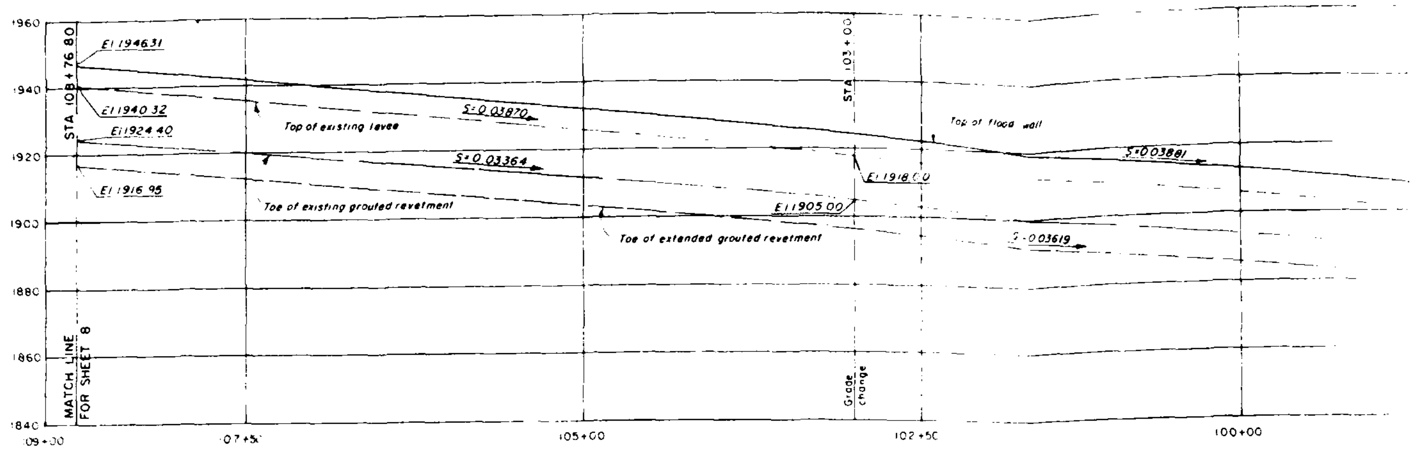
REVISIONS

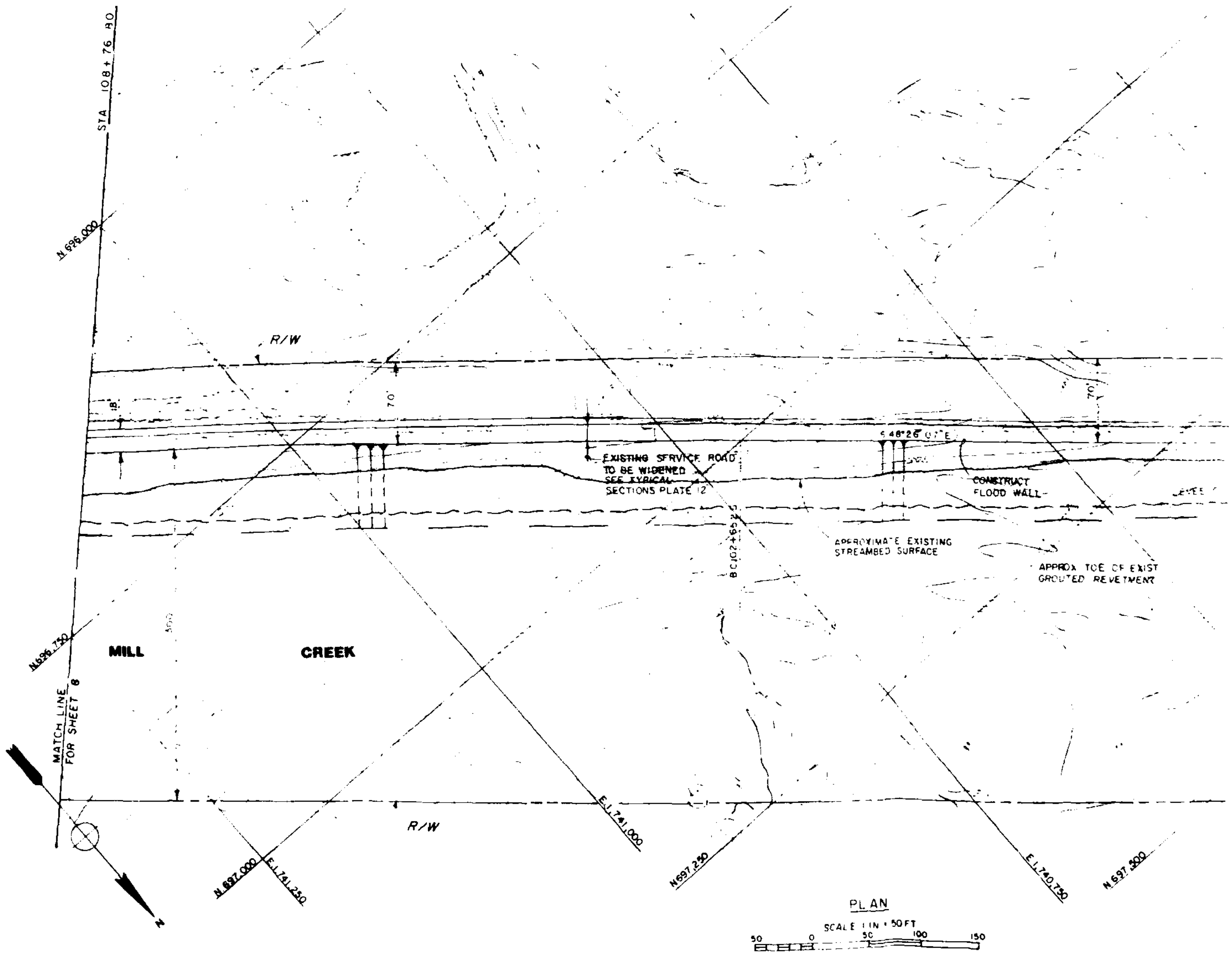
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE
PLAN AND PROFILE
STA 121+81.57 TO STA 108+76.80

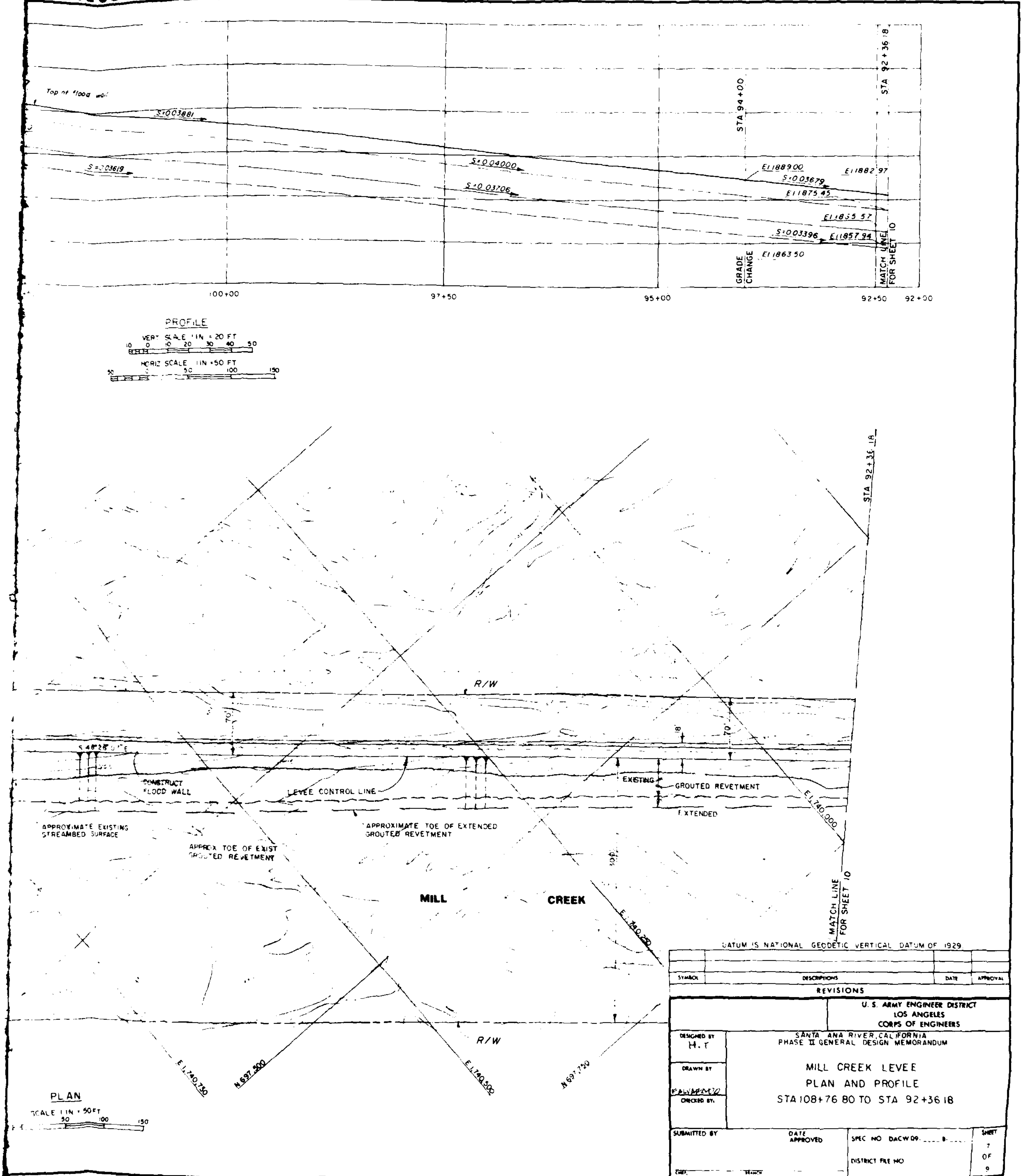
DESIGNED BY: H. T.
DRAWN BY: P. CASTELLANOS
CHECKED BY:
SUBMITTED BY:
DATE APPROVED
SPEC NO DACW09-
DISTRICT FILE NO
SHEET 6 OF 9





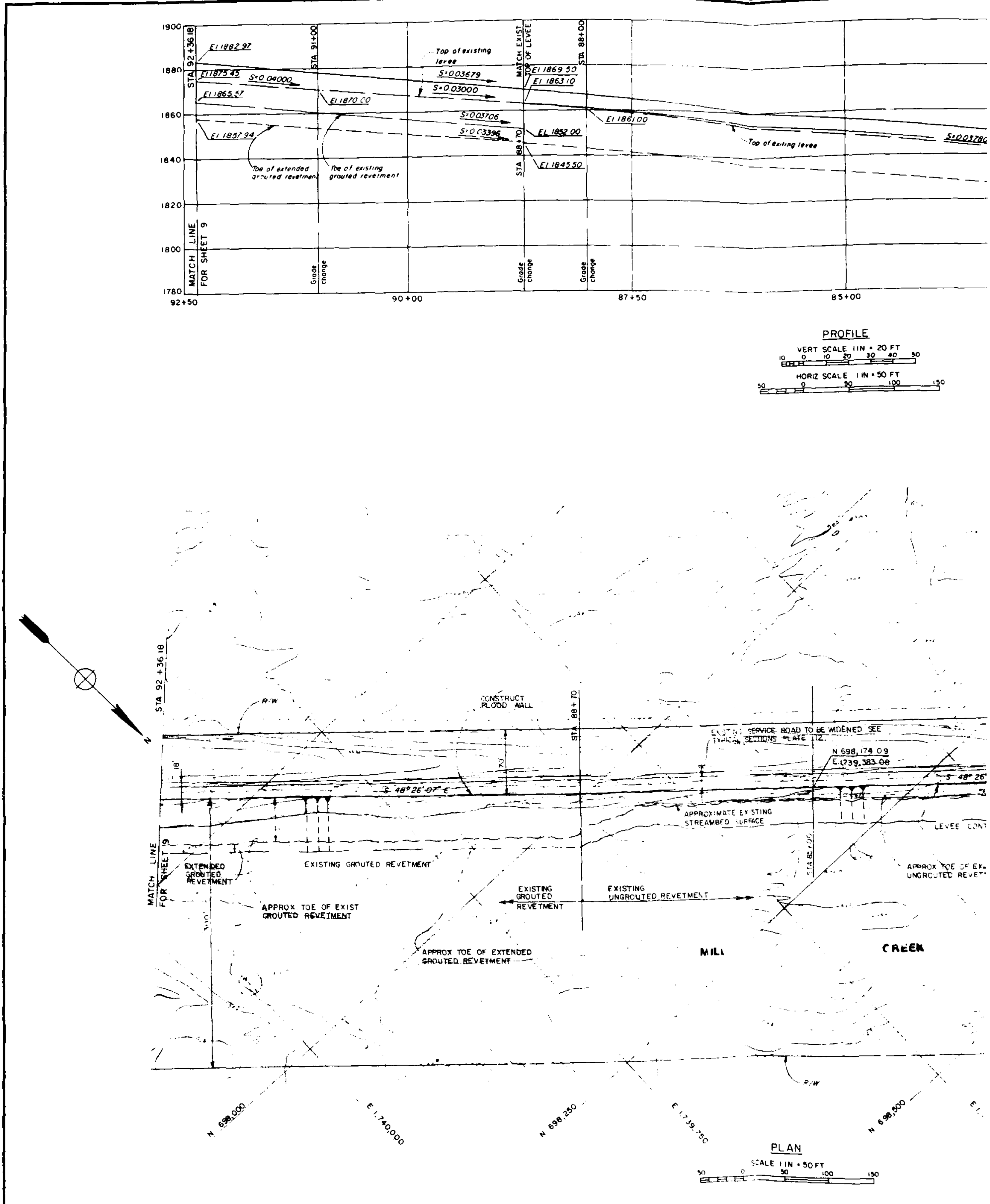
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

VALUE ENGINEERING PAYS

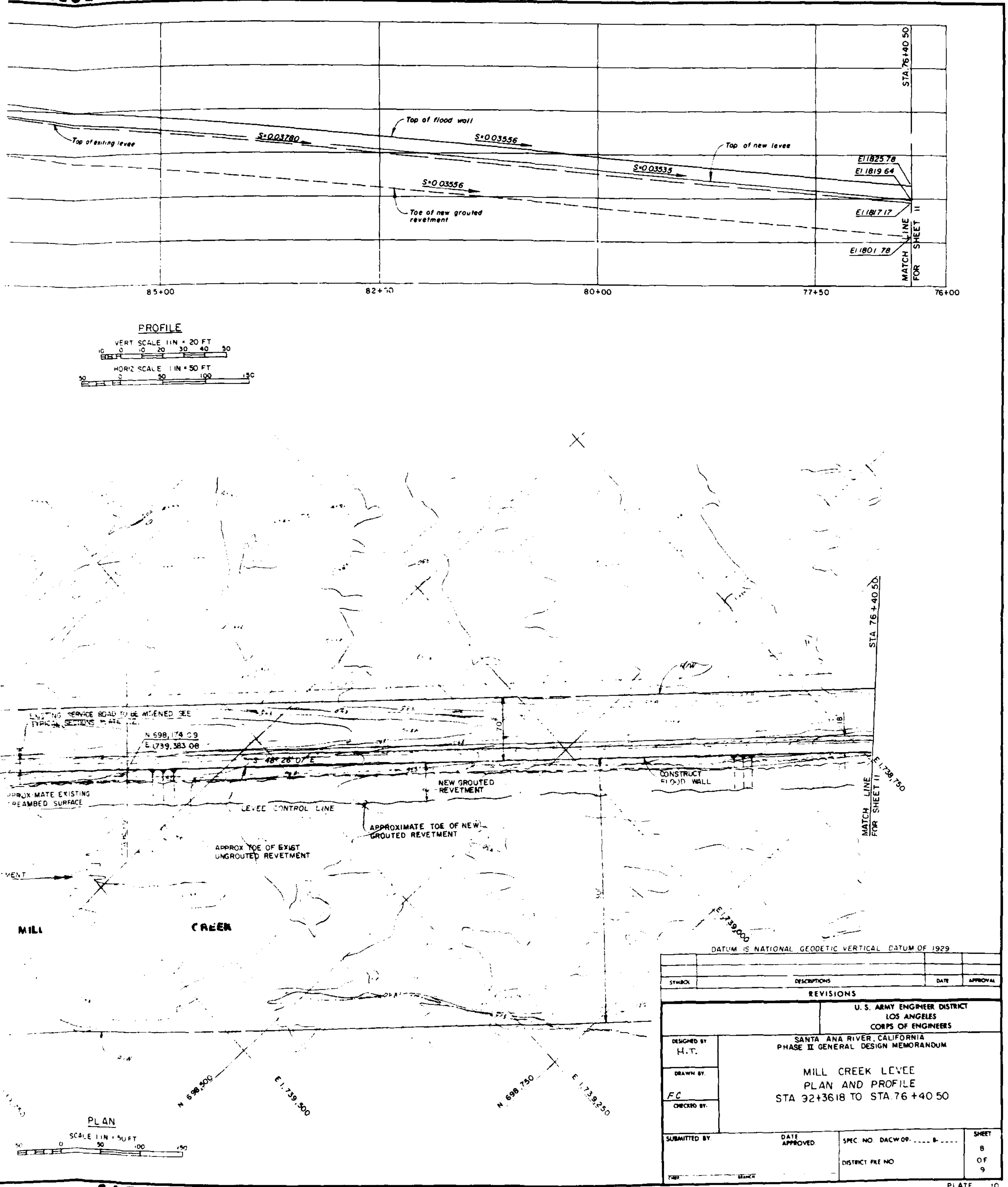


SAFETY PAYS

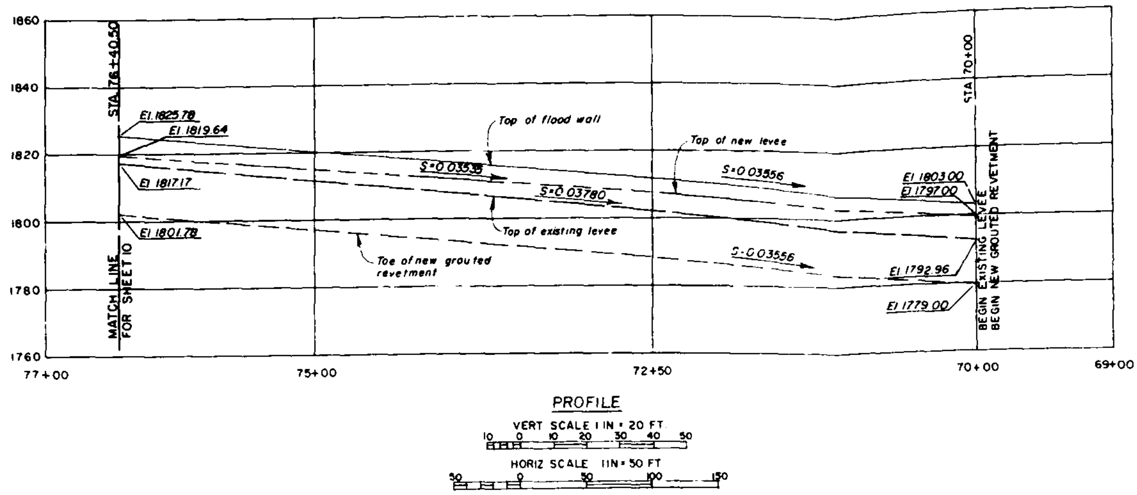
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



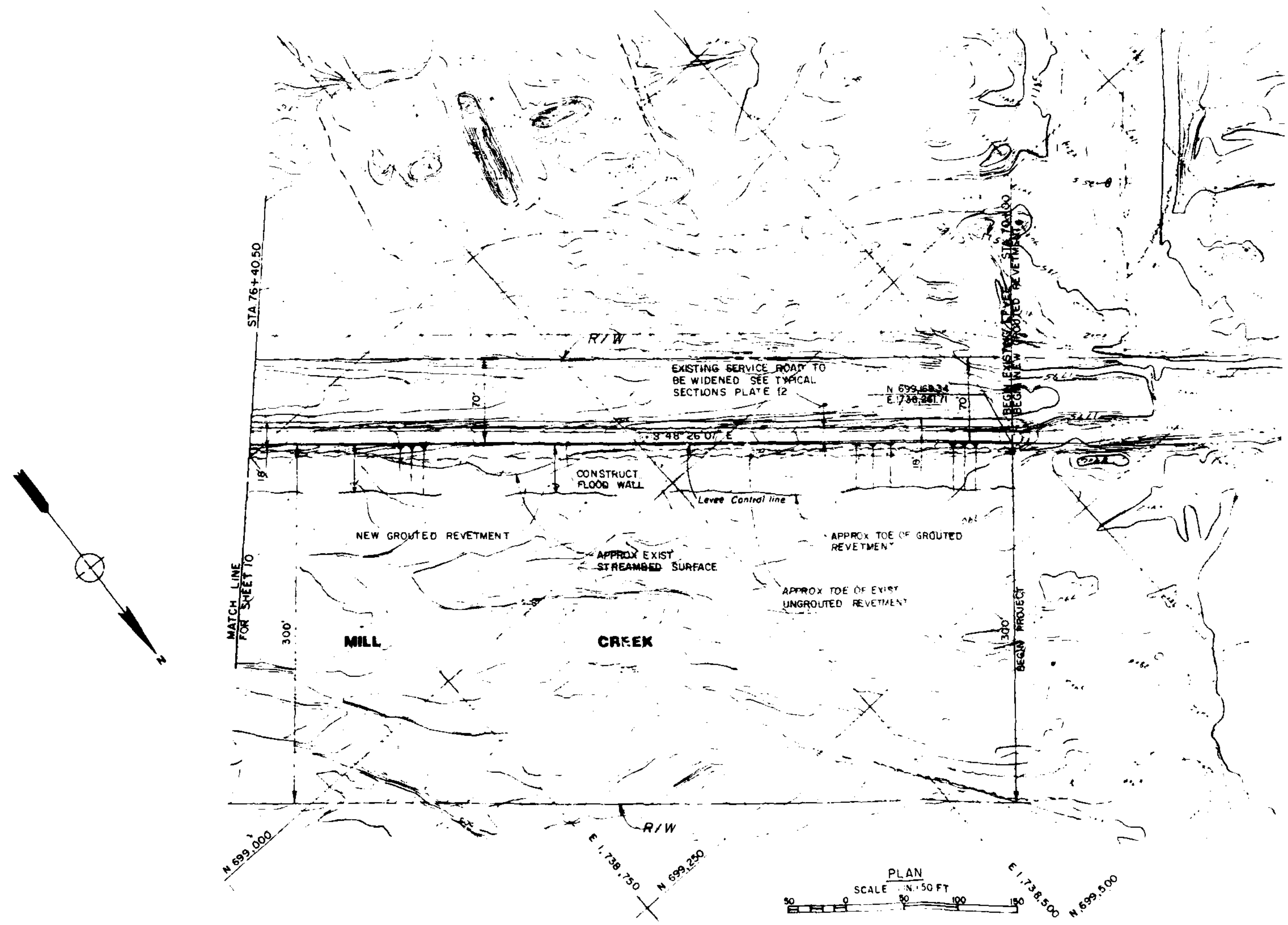
VALUE ENGINEERING PAYS



SAFETY PAYS

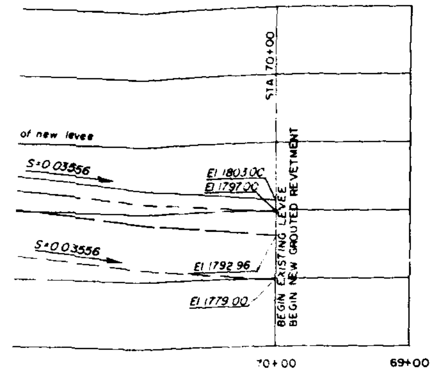


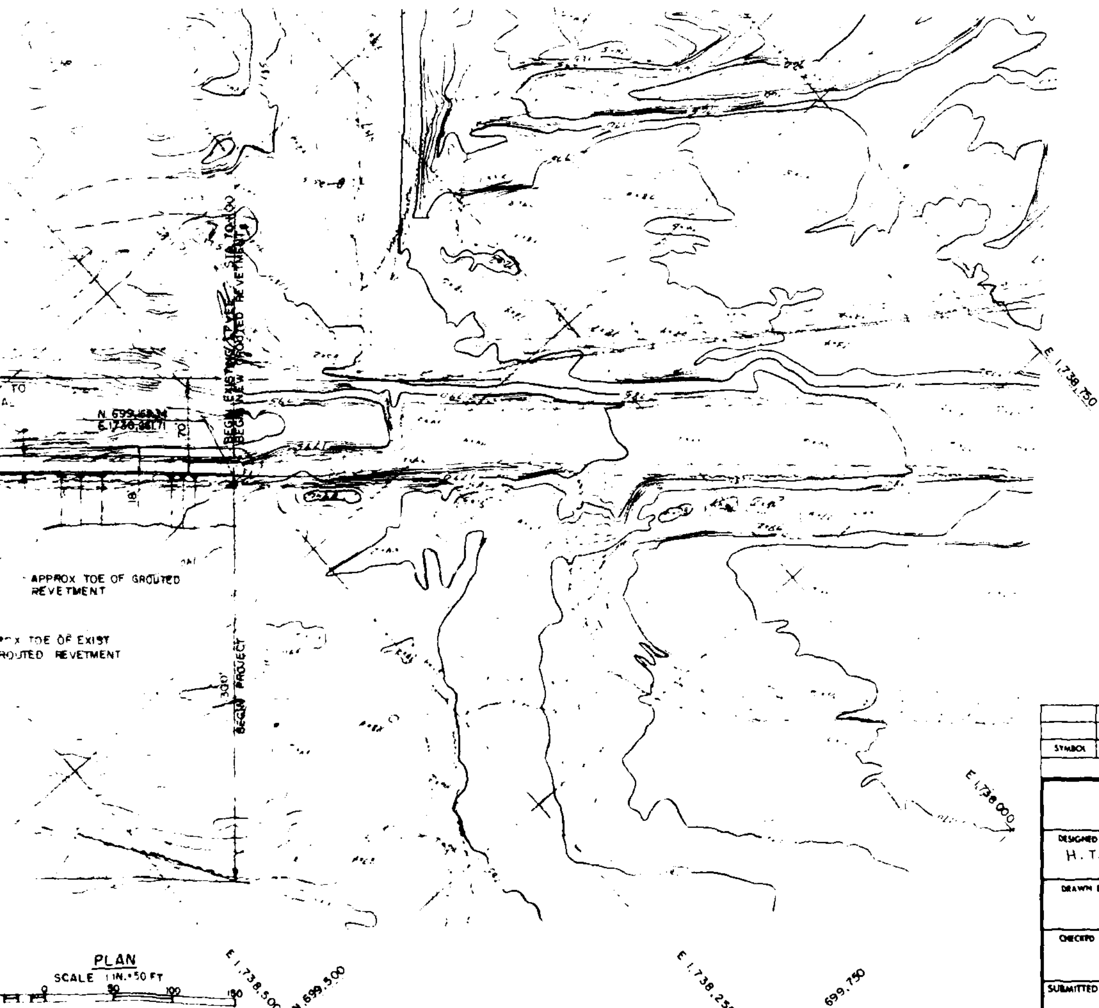
1860
1840
1820
1800
1780
1760
77+00
75+00
72+50
70+00
69+00
STA 76+40.50
STA 70+00
El 1825.78
El 1819.64
El 1817.17
El 1801.78
Top of flood wall
Top of new levee
Top of existing levee
S=0.03556
S=0.03780
S=0.03556
Toe of new grouted revetment
El 1803.00
El 1797.00
El 1792.96
El 1779.00
MATCH LINE FOR SHEET 10
BEGIN EXISTING LEVEE
BEGIN NEW GROUTED REVETMENT
PROFILE
VERT SCALE 1 IN = 20 FT
HORIZ SCALE 1 IN = 50 FT



STA 76+40.50
R/W
EXISTING SERVICE ROAD TO BE WIDENED SEE TYPICAL SECTIONS PLATE 12
N 699,168.34
E 1,738,561.71
70'
19'
CONSTRUCT FLOOD WALL
Levee Control line
NEW GROUTED REVETMENT
APPROX EXIST STREAMBED SURFACE
APPROX TOE OF GROUTED REVETMENT
APPROX TOE OF EXIST UNGROUTED REVETMENT
MATCH LINE FOR SHEET 10
300'
MILL
CREEK
BEGIN PROJECT
BEGIN EXISTING LEVEE
BEGIN NEW GROUTED REVETMENT
R/W
N 699,000
E 1,738,750
N 699,250
E 1,738,500
N 699,500
N
PLAN
SCALE 1 IN = 50 FT

VALUE ENGINEERING PAYS





PLAN

SCALE 1 IN. = 50 FT

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY H. T.

DRAWN BY

CHECKED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE
PLAN AND PROFILE
STA 76+40.50 TO STA 70+00

SUBMITTED BY

DATE APPROVED

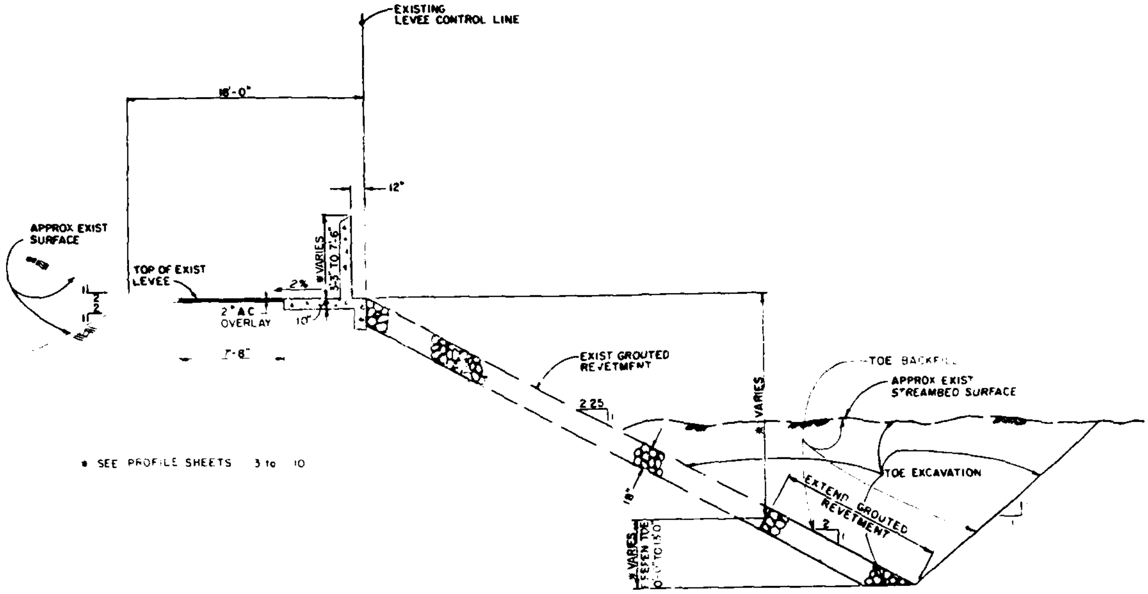
SPEC NO. DACW09-

DISTRICT FILE NO

SHEET 9 OF 9

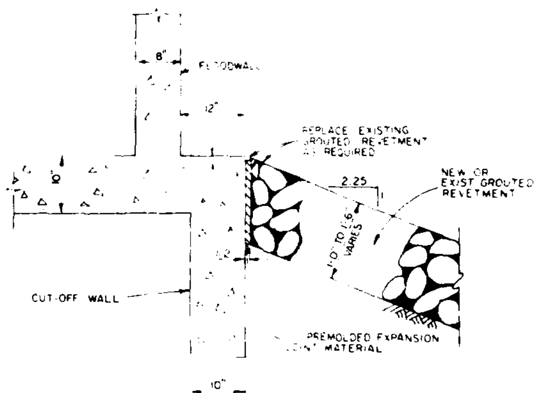
PLATE 11

SAFETY PAYS

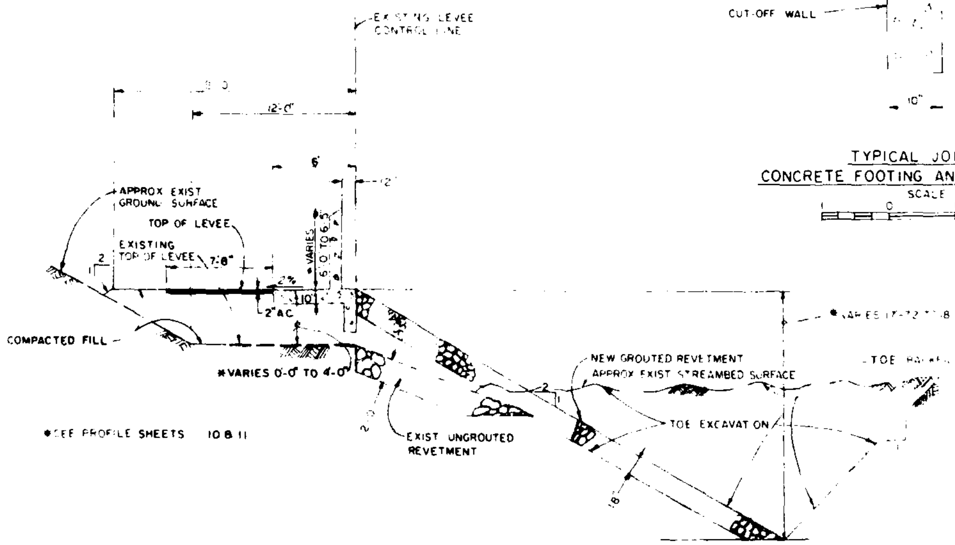


TYPICAL SECTION
STA 88+70 TO STA 130+20
STA 130+72 TO STA 196+25.37

SCALE 1 IN = 5 FT

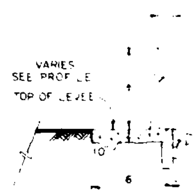


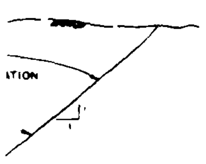
TYPICAL JOINT SECTION
CONCRETE FOOTING AND GROUTED REVETMENT

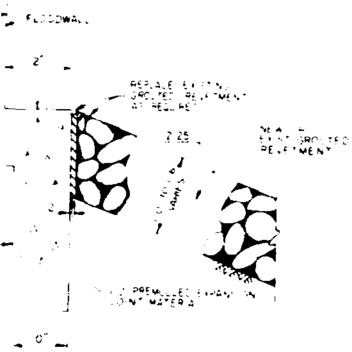


TYPICAL SECTION
STA 70+00 TO STA 88 + 70

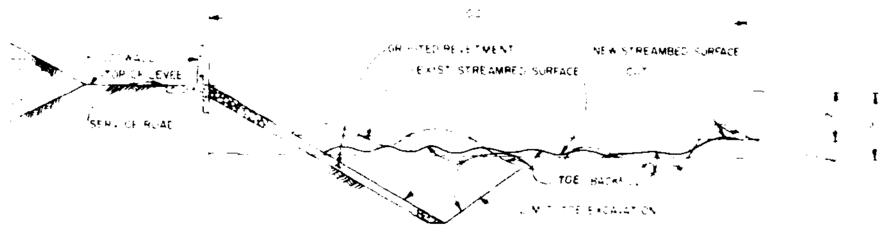
SCALE 1 IN = 5 FT





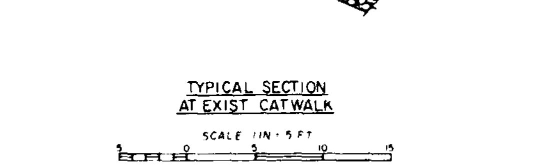


PICAL JOINT SECTION
OTING AND GROUTED REVETMENT
SCALE



GENERAL NOTE

TYPICAL STREAMBED SURFACE RANDOM BACKFILL



TYPICAL SECTION
AT EXIST CATWALK

SCALE 1 IN = 5 FT

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DRAWN BY

MILL CREEK LEVEE
LEVEE CROSS SECTIONS

CHECKED BY

SUBMITTED BY

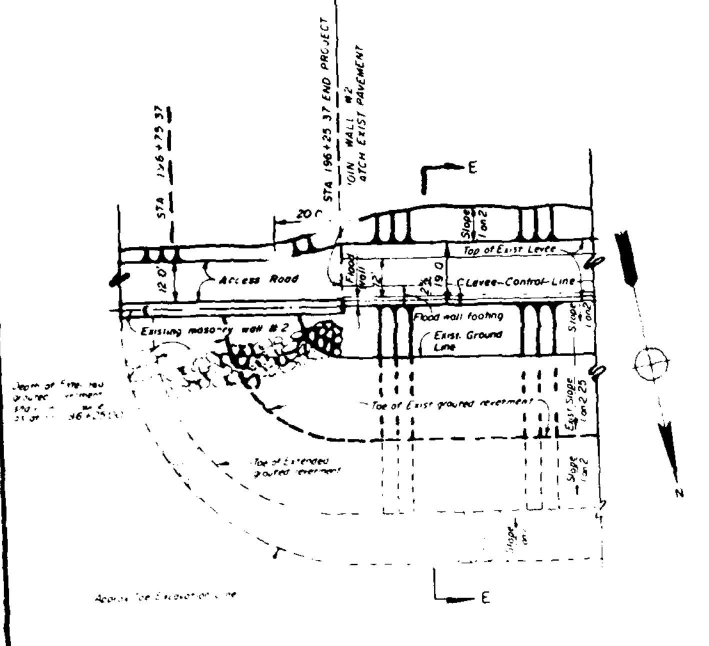
DATE APPROVED

SPEC NO DACW09

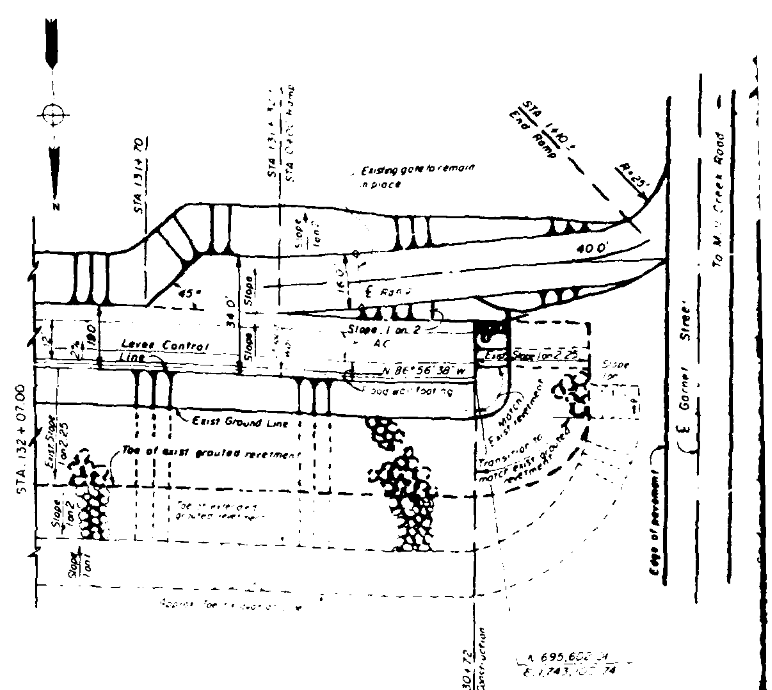
DISTRICT FILE NO

SHEET

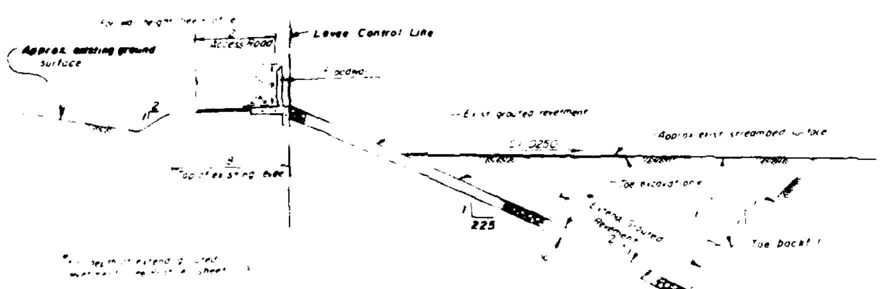
OF



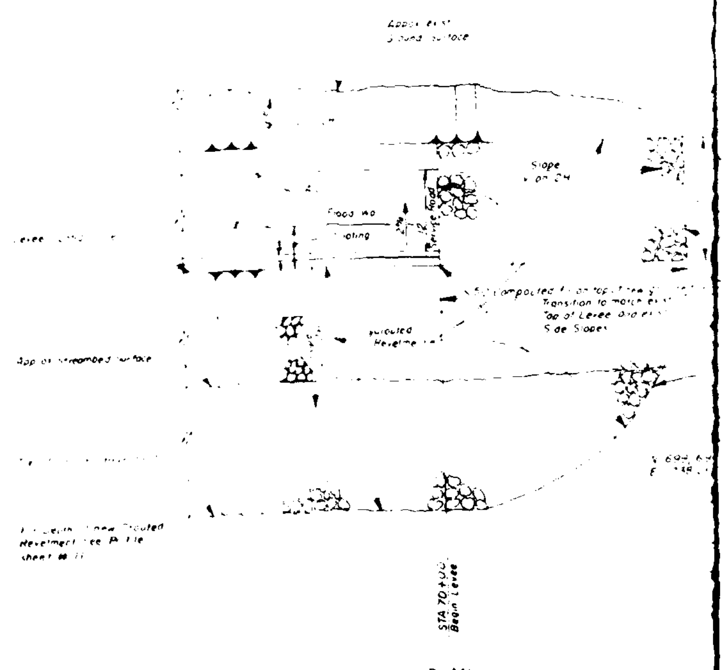
LEVEE TERMINUS AT STA 196 + 25.37
SCALE 1"=20 FT



PLAN
LEVEE TERMINUS AT STA 130+72



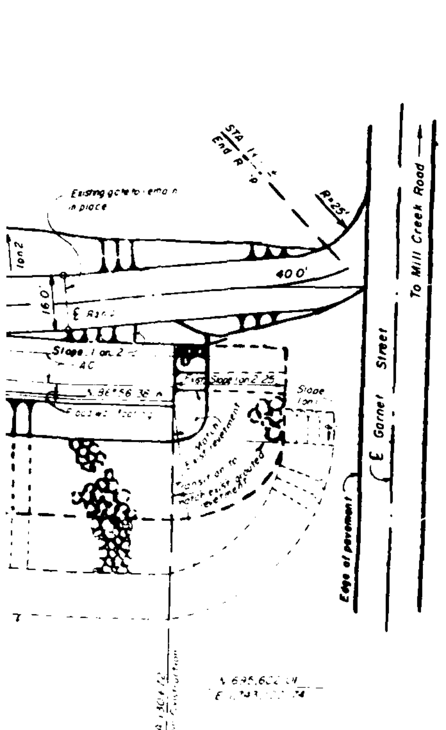
SECTION E-E



PLAN
LEVEE TERMINUS AT STA 70+00

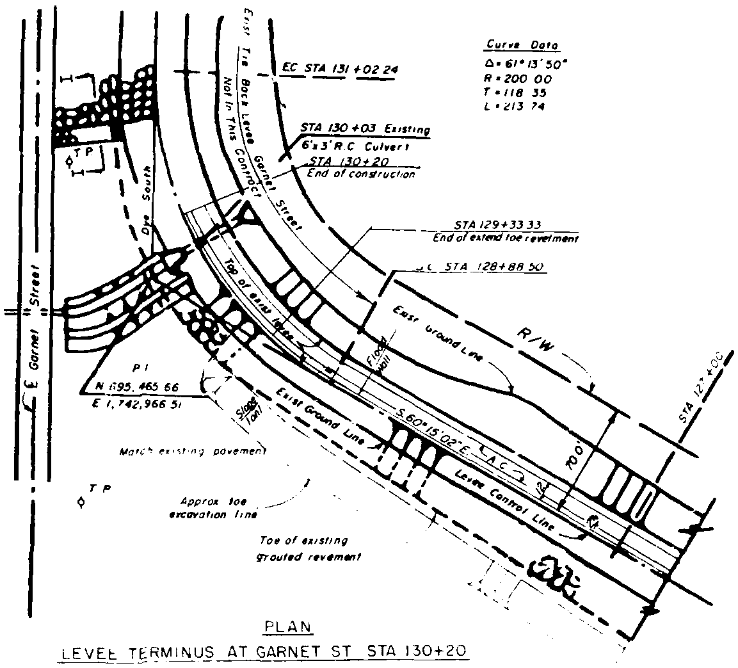
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING

VALUE ENGINEERING PAYS



PLAN

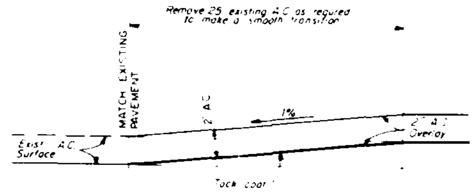
LEVEE TERMINUS AT STA 132+...



PLAN

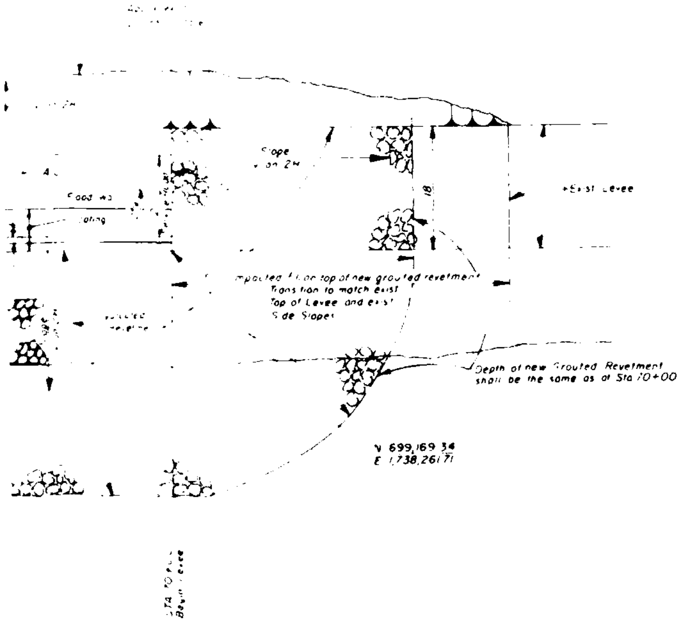
LEVEE TERMINUS AT GARNET ST STA 130+20

SCALE 1 IN = 40 FT



TYPICAL ℄ SERVICE ROAD TRANSITION

NOT TO SCALE



PLAN

LEVEE TERMINUS AT STA 70+00

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DRAWN BY

CHECKED BY

MILL CREEK LEVEE
LEVEE TERMINUS AND
TRANSITION DETAILS

SUBMITTED BY

DATE APPROVED

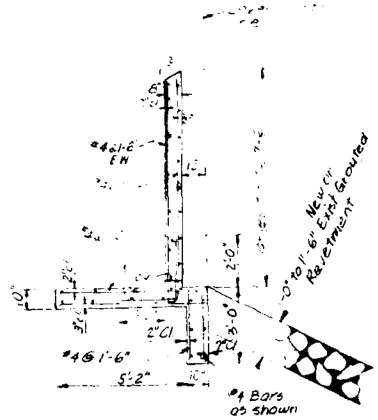
SPEC NO. DACW09

SHEET OF

DISTRICT FILE NO.

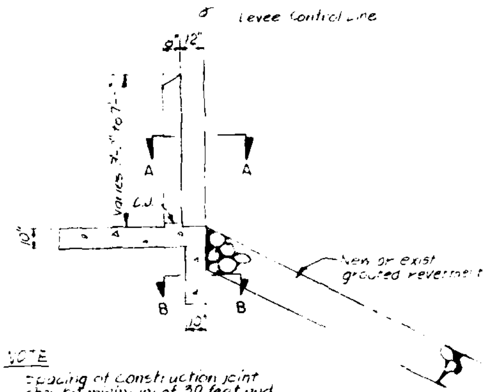
PLATE 13

SAFETY PAYS



TYPICAL FLOODWALL SECTION

SCALE 3/8 IN = 1 FT

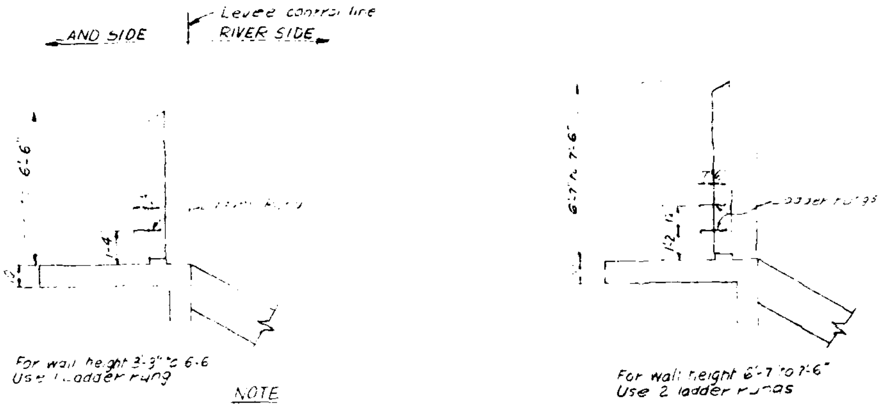


NOTE

Spacing of construction joint shall be minimum of 30 feet and maximum of 60 feet

TYPICAL VERTICAL WALL JOINT

SCALE 3/8 IN = 1 FT



NOTE

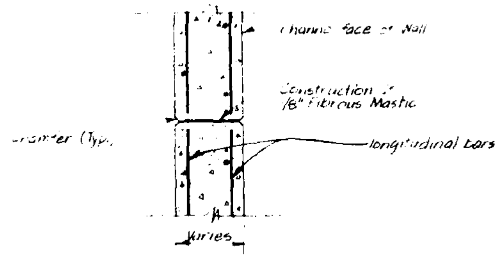
[illegible] ladders shall be on Land Side at 300' Spacing for the East and West from the following stations:

(1) Sta 118 + [illegible] (For Sta 70+00 to Sta 13[illegible]+20)

(2) Sta. 1[illegible]7+00 (For Sta 30+72 to Sta 196+25.37)

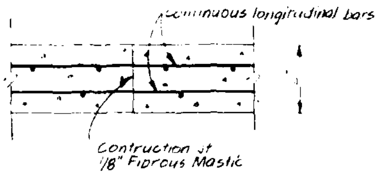
TYPICAL LADDER ON FLOODWALL

SCALE 3/8 IN = 1 FT



SECTION A-A

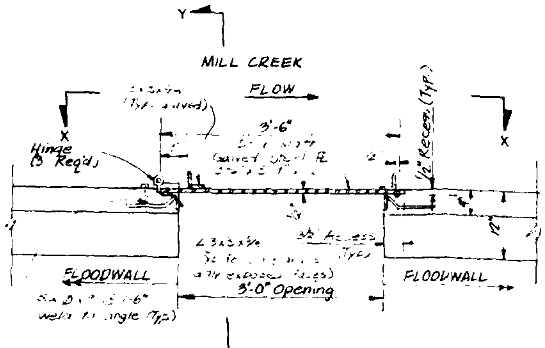
SCALE 1 IN = 1 FT



SECTION B-B

SCALE [illegible] = 1 FT

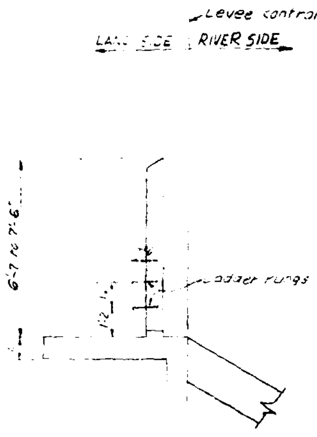
ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



PLAN

TYPICAL FLOODWALL GATE

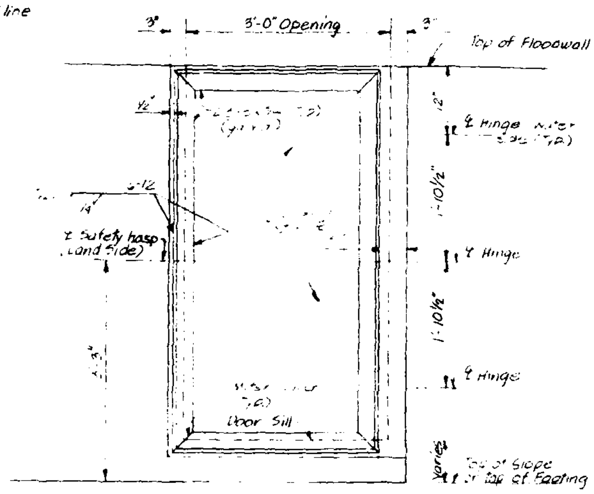
SCALE 1 IN = 1 FT



For wall height 6'-7" to 7'-6"
Use 3 ladder rungs

... Side at 300' spacing
... the following stations
... Sta 70+00 to Sta 13...+2C)
... Sta 30+72 to Sta 96+25.37)

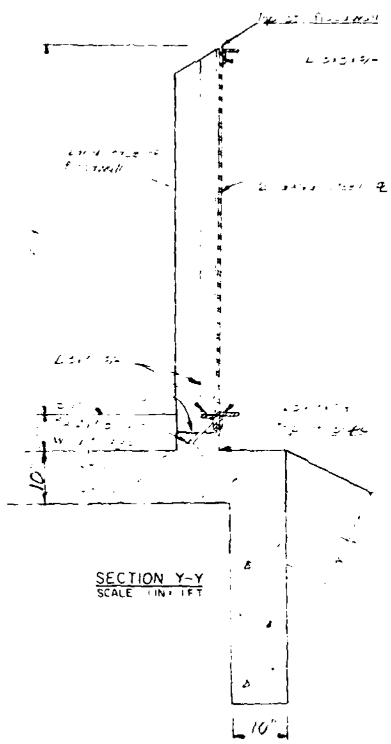
...ON FLOODWALL



SECTION X-X

TYPICAL FLOODWALL GATE

SCALE 1 IN = 1 FT

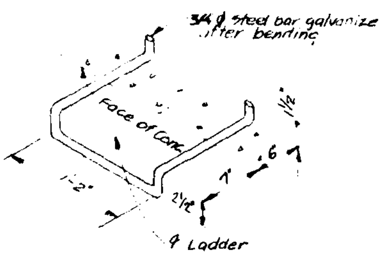


SECTION Y-Y

SCALE 1 IN = 1 FT

NOTES

1. Gates shall be install at Sta 118+10 and Sta ...
2. Hinge capacity shall be minimum 300# each
3. Provide safety hasp on landward side



LADDER RUNG DETAIL

SCALE 1 1/2 IN = 1 FT

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

DRAWN BY

P. PANEUETA

CHECKED BY

MILL CREEK LEVEE

STRUCTURE, LADDER AND GATE DETAILS

SUBMITTED BY

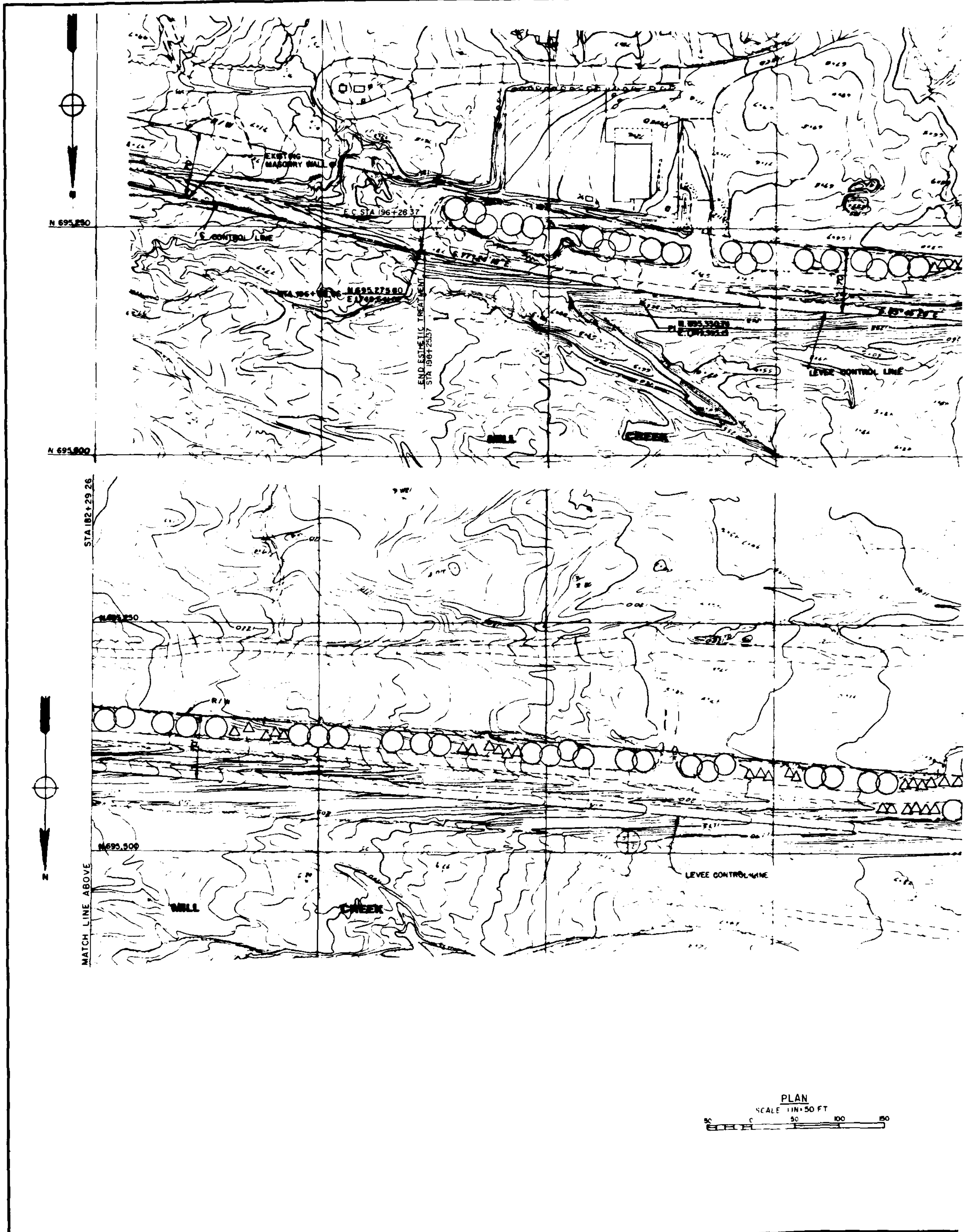
DATE APPROVED

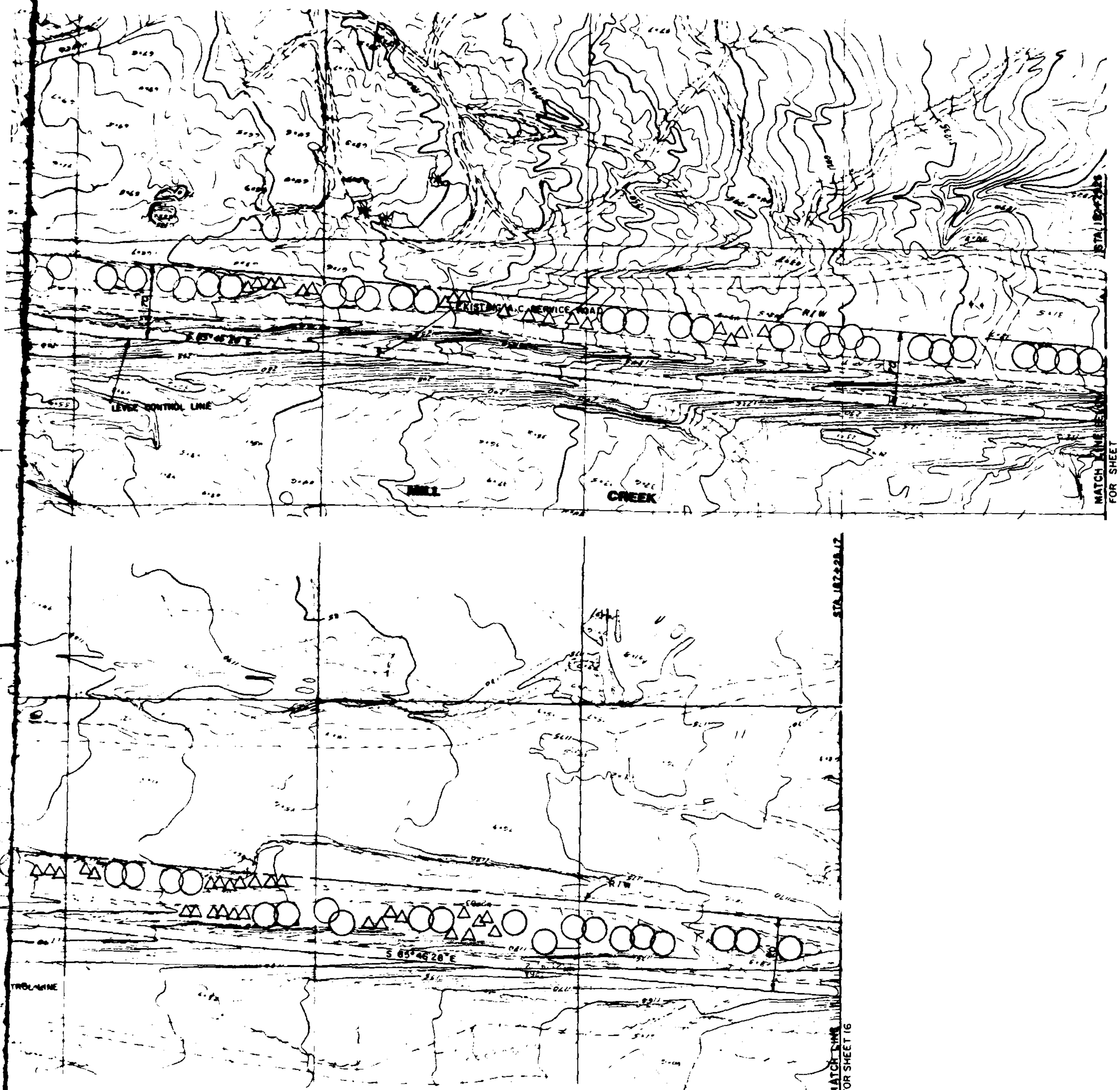
SPEC NO DACW09-

DISTRICT FILE NO

SHEET OF

ENVIRONMENTAL
ENHANCEMENT
THRU ENGINEERING





DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

LEGEND

TYPICAL TREE GROUPING FOR SCREENING FLOODWALL

TYPICAL SHRUB GROUPING TO BREAK UP LONG LINEAR VIEW OF LEVEE

PLAN
SCALE 1 IN = 50 FT
0 50 100 150

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: EBL
DRAWN BY: EBL
CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

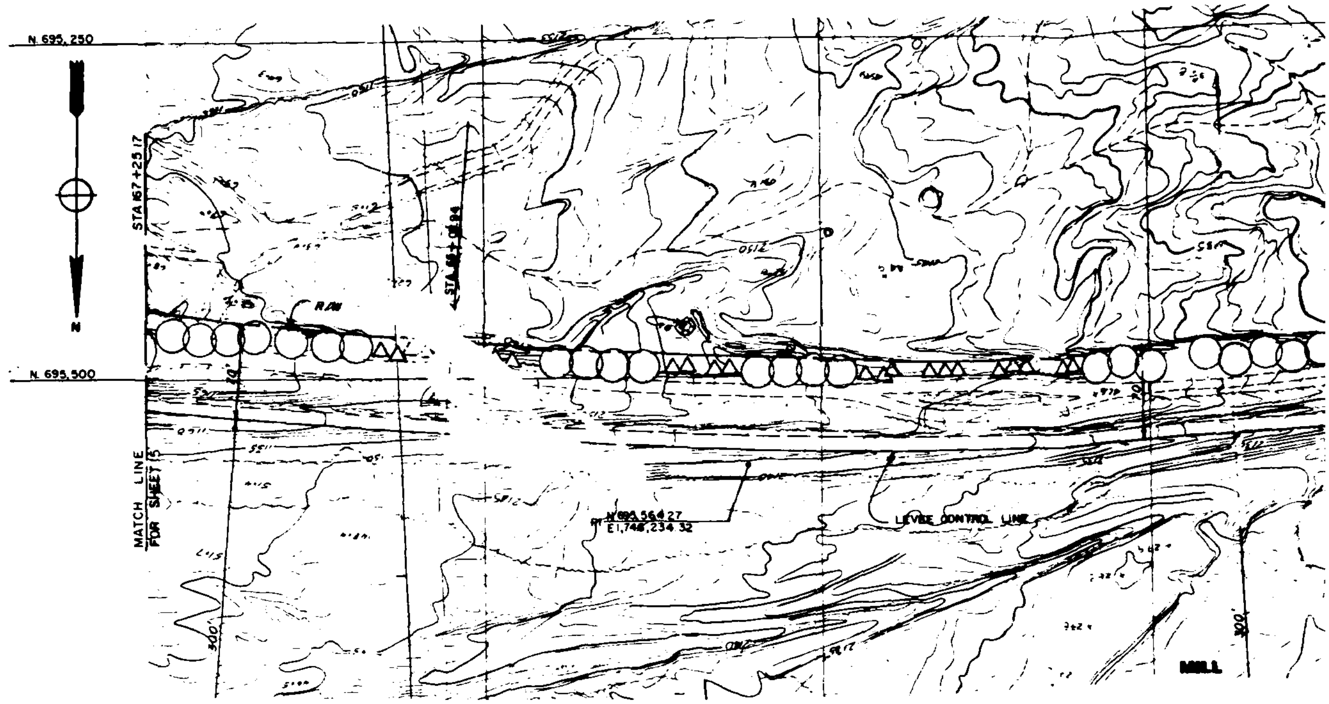
MILL CREEK LEVEE

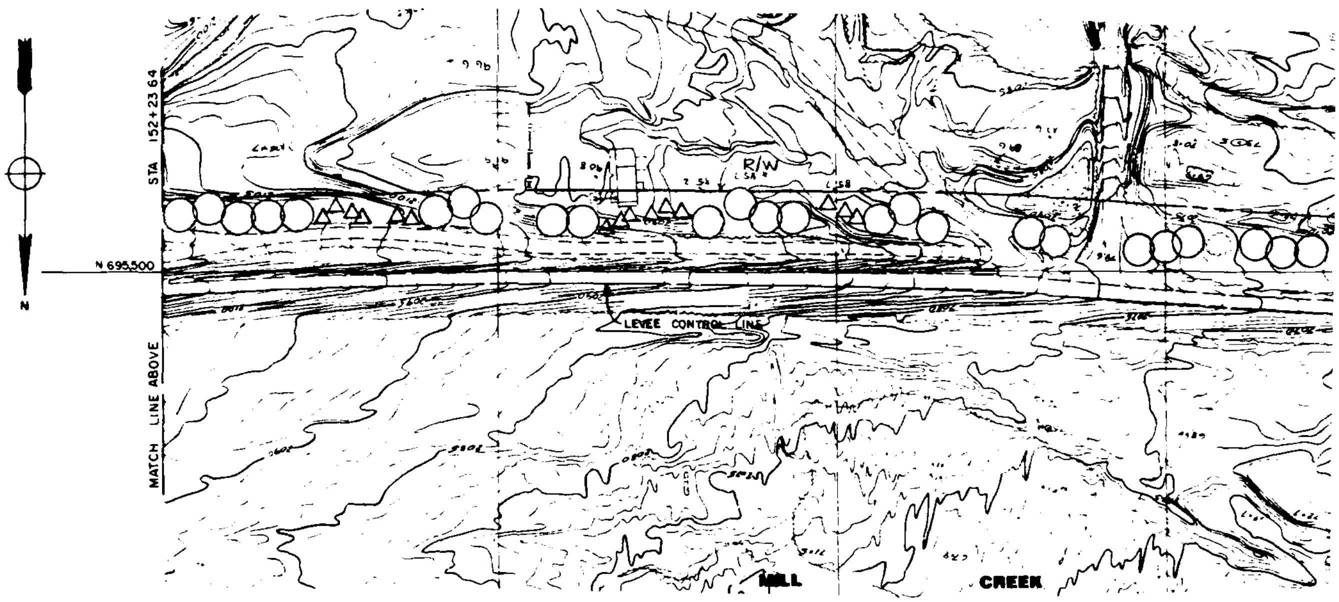
ESTHETIC TREATMENT PLAN
STA 196+25.37 TO STA 182+29.26
STA 182+29.26 TO STA 167+25.17

SUBMITTED BY:
DATE APPROVED:
SPEC. NO. DACW09-___-B-____
DISTRICT FILE NO.
SHEET 1 OF 3

PLATE 15

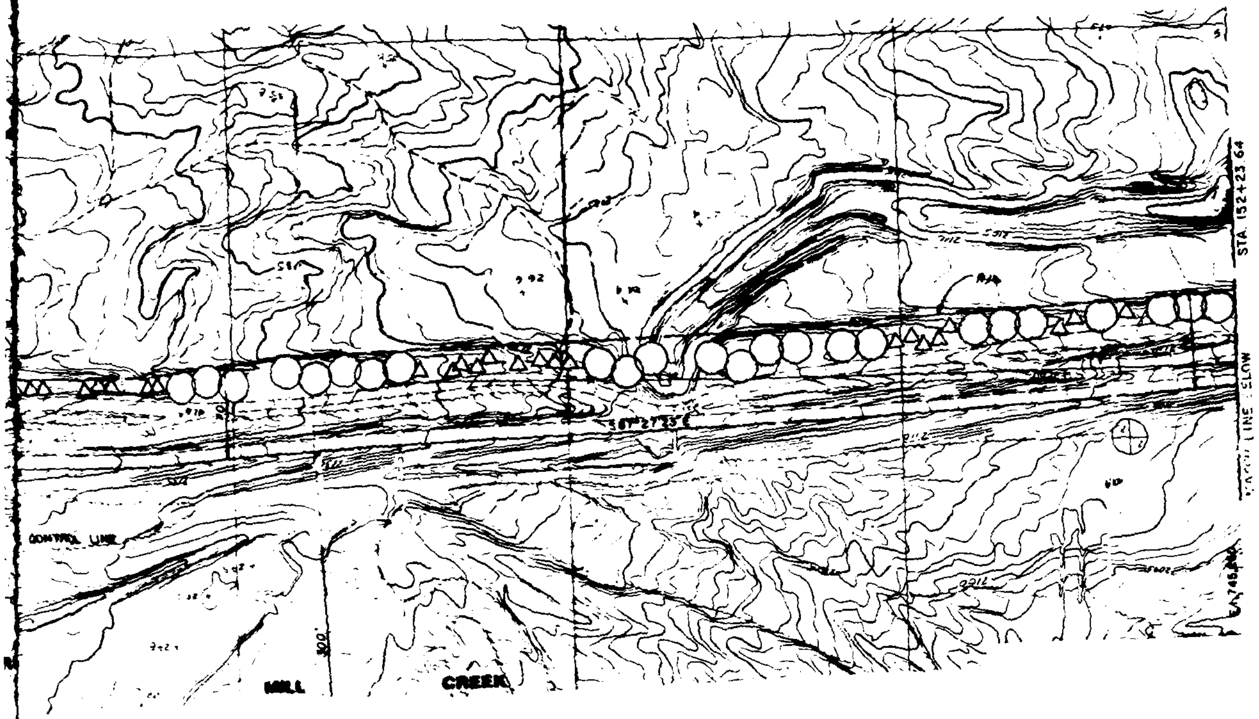
ENVIRONMENTAL
ENHANCEMENT
THRU ENGINEERING

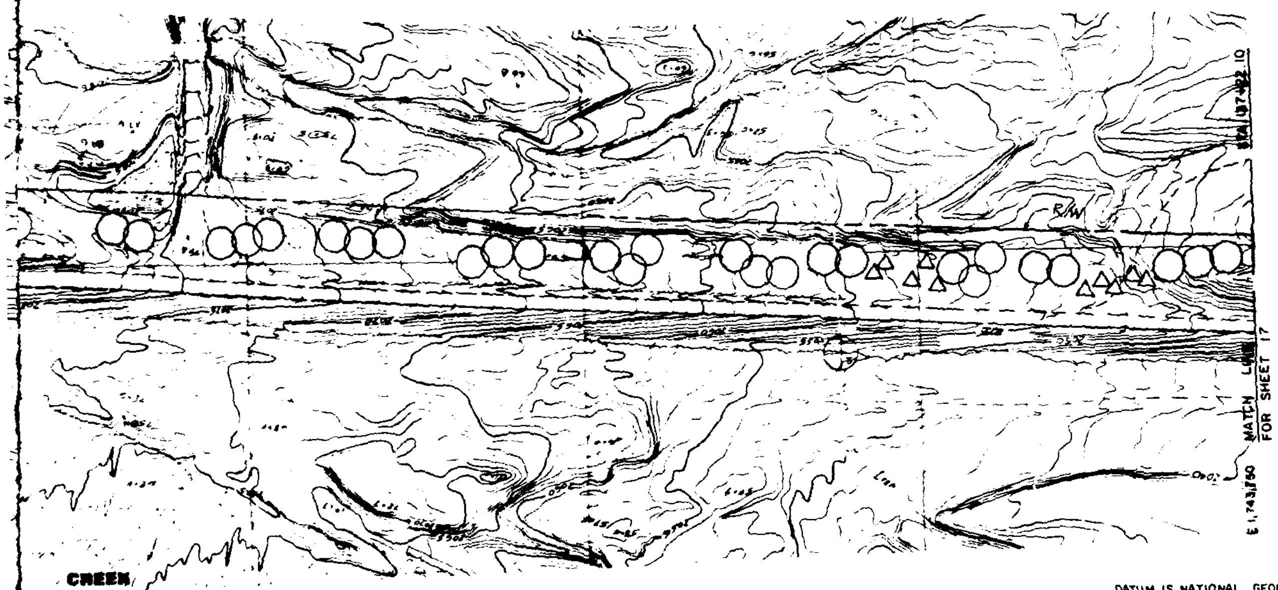




PLAN
SCALE 1 IN = 50 FT

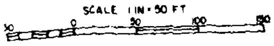
VALUE ENGINEERING PAYS





PLAN

SCALE 1 IN = 50 FT



LEGEND

TYPICAL TREE GROUPING FOR SCREENING FLOODWALL

TYPICAL SHRUB GROUPING TO BREAK UP LONG LINEAR VIEW OF LEVEE

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY: EDL

DRAWN BY: EDL

CHECKED BY:

SANTA ANA RIVER, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE

ESTHETIC TREATMENT PLAN
STA 167+25.17 TO STA 152+23.64
STA 152+23.64 TO STA 137+22 10

SUBMITTED BY:

DATE APPROVED:

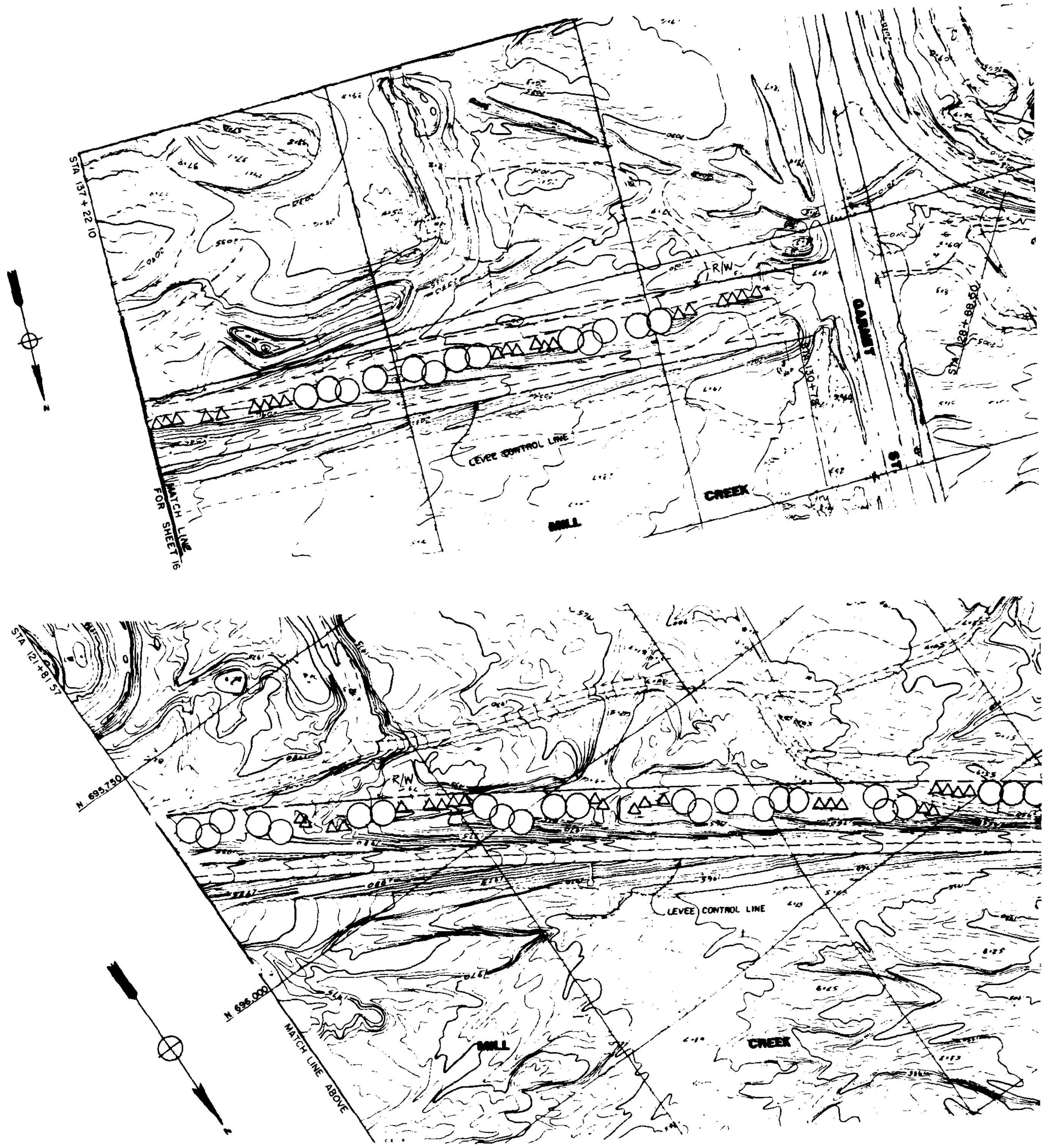
SPEC. NO. DACW09- ____ B- ____

DISTRICT FILE NO.

SHEET 2 OF 3

PLATE 16

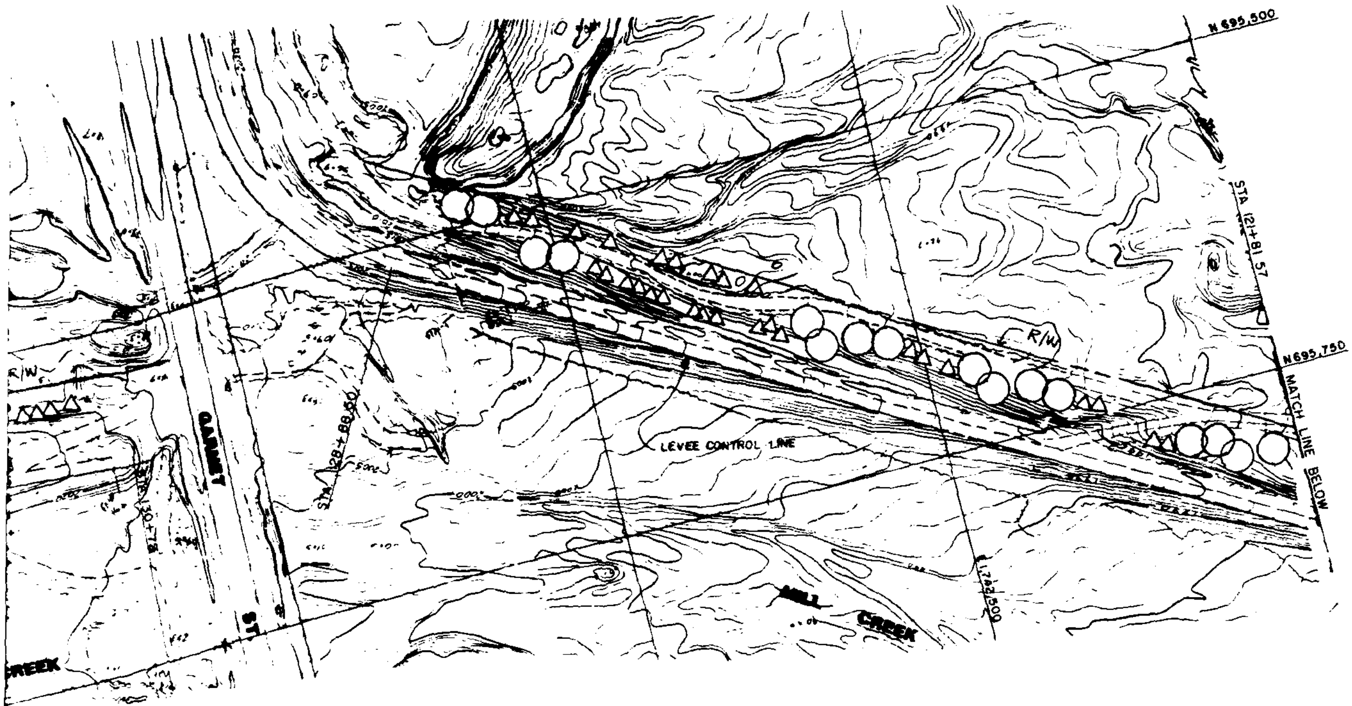
SAFETY PAYS

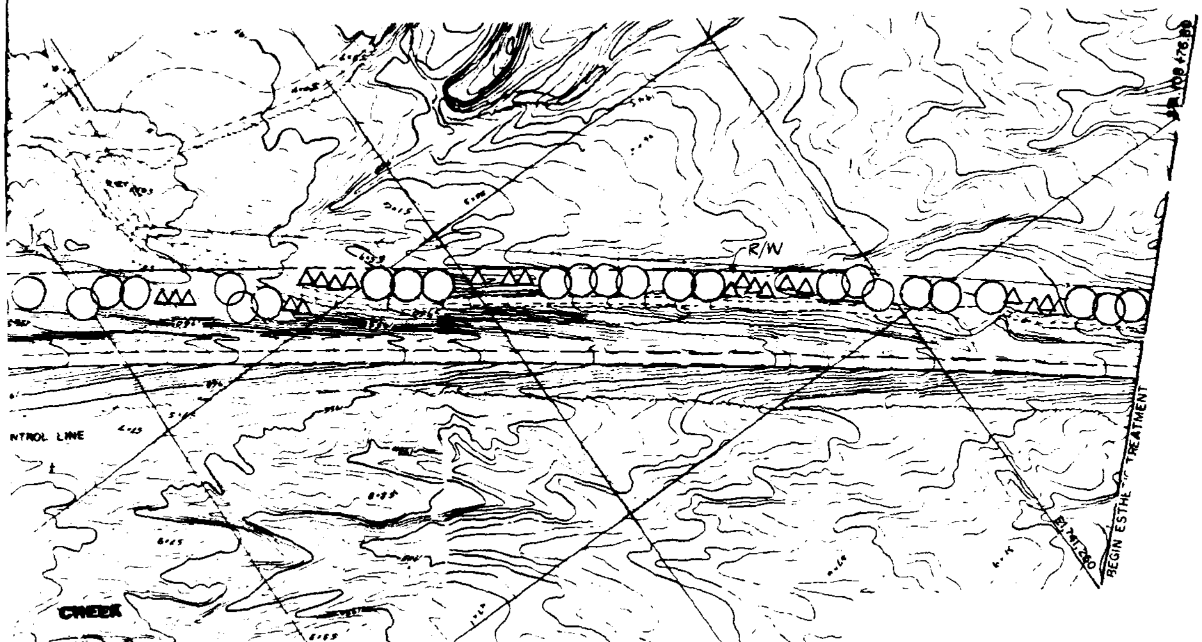


PLAN

SCALE 1 IN = 50 FT

-NVIRONMENTAL ENHANCEMENT THRU ENGINEERING





LEGEND

- TYPICAL TREE GROUPING FOR SCREENING FLOODWALL
- TYPICAL SHRUB GROUPING TO BREAK UP LONG LINEAR VIEW OF LEVEE

PLAN
SCALE 1 IN = 50 FT
50 100 150

DATUM IS NATIONAL GEODETIC VERTICAL DATUM OF 1929

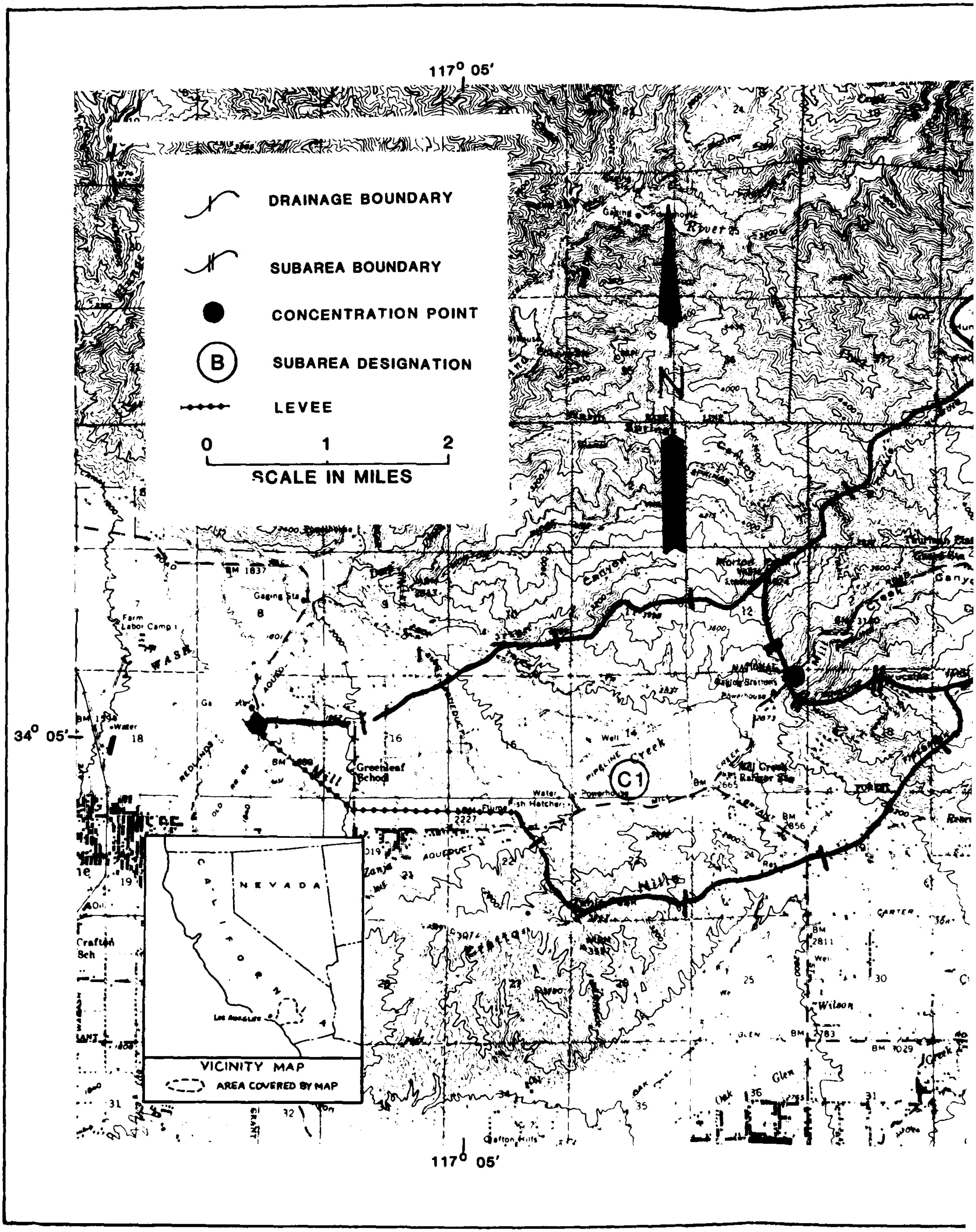
SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

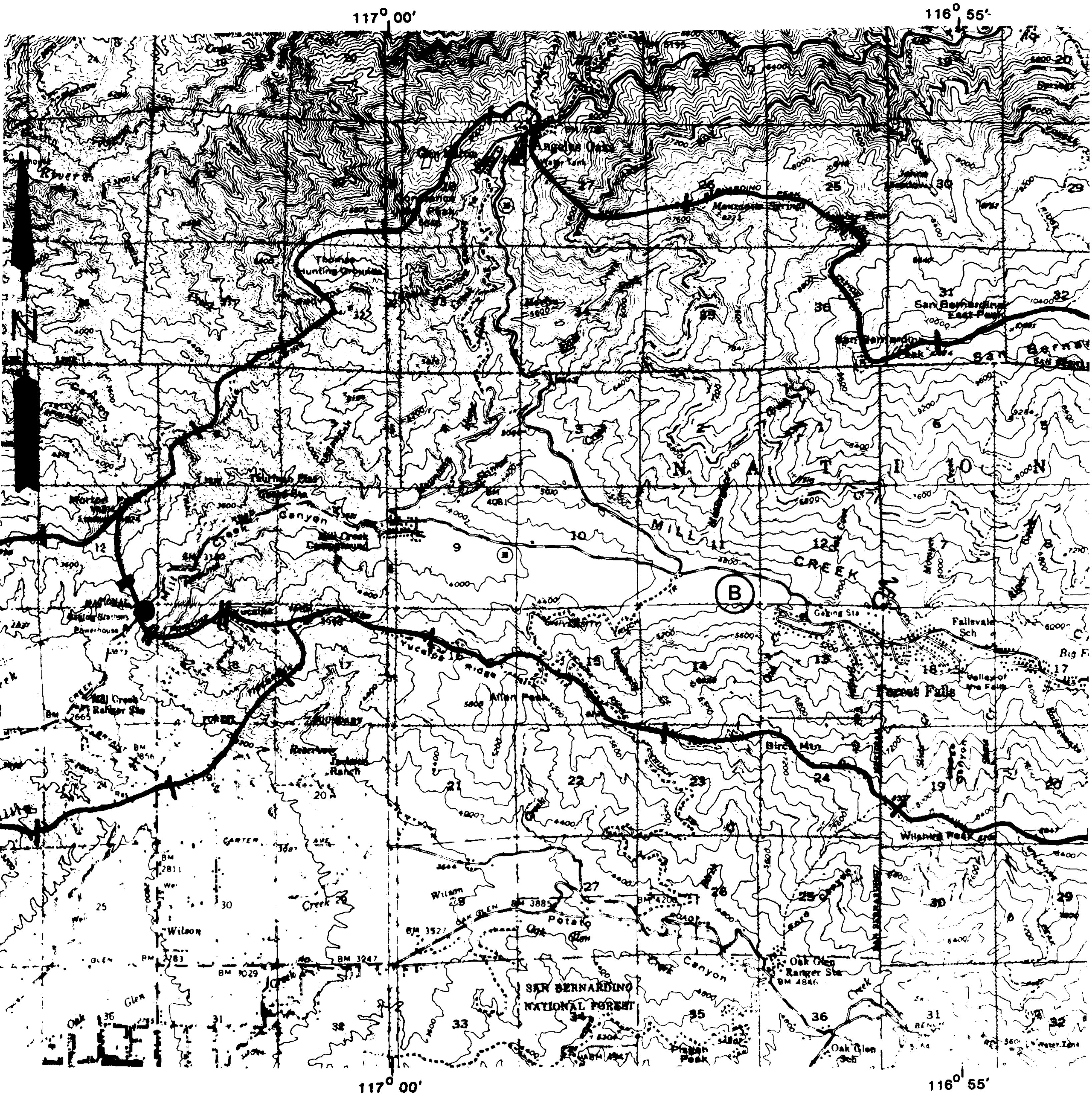
U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

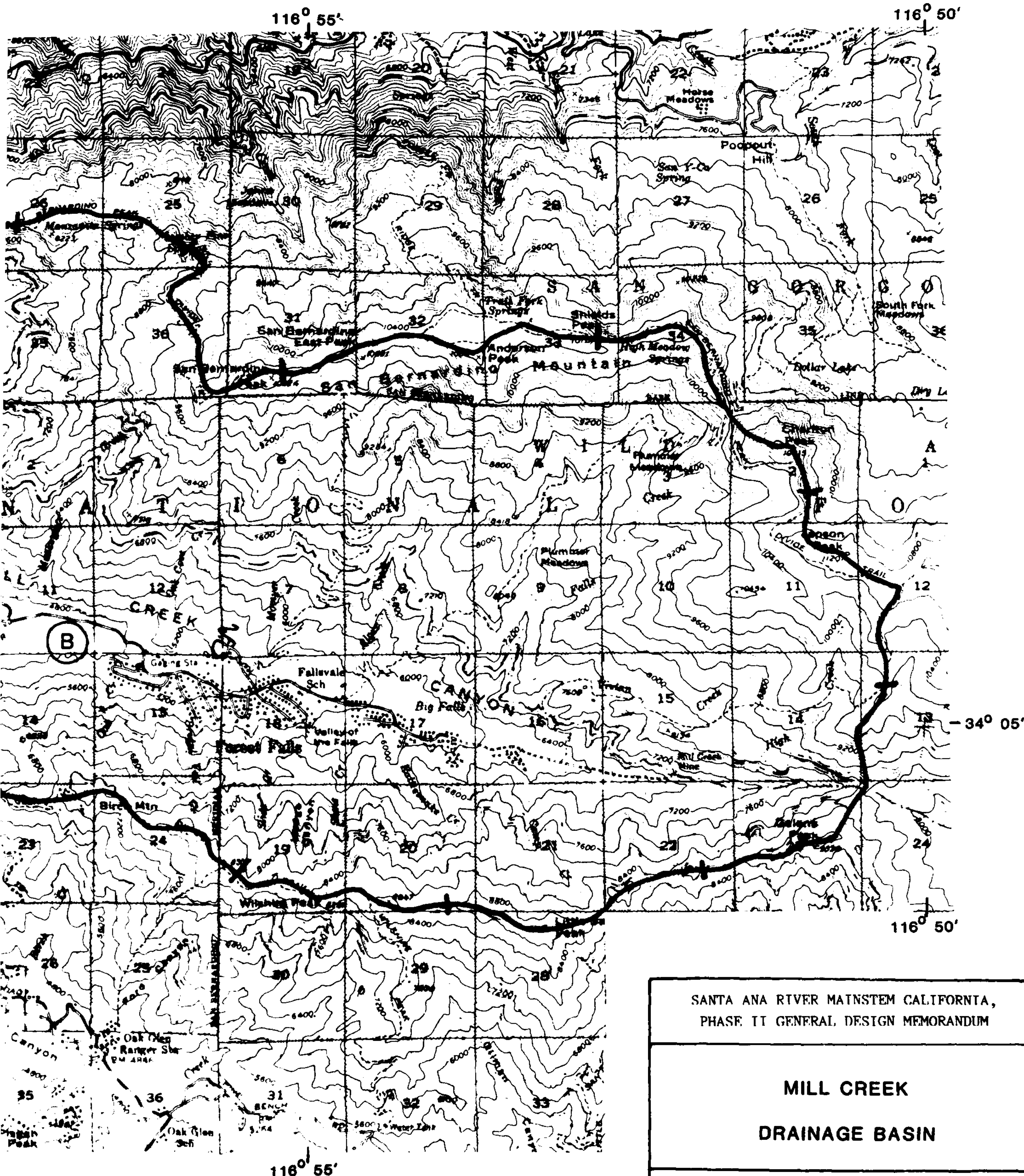
DESIGNED BY: EBL	SANTA ANA RIVER, CALIFORNIA PHASE II GENERAL DESIGN MEMORANDUM
DRAWN BY: EBL F.C.	MILL CREEK LEVEE
CHECKED BY:	ESTHETIC TREATMENT PLAN STA.137+22.10 TO STA.121+81.57 STA.121+81.57 TO STA.108+76.80
SUBMITTED BY:	DATE APPROVED: — SPEC. NO. DACW 09 ___ B ___ — DISTRICT FILE NO. — SHEET 3 OF 3

PLATE 17



117° 05'
DRAINAGE BOUNDARY
SUBAREA BOUNDARY
CONCENTRATION POINT
B
SUBAREA DESIGNATION
LEVEE
0
1
2
SCALE IN MILES
N
C1
34° 05'
Greenleaf School
VICINITY MAP
AREA COVERED BY MAP
NEVADA
CALIFORNIA
117° 05'


117° 00'
116° 55'
B
MILL CREEK
Mill Creek Canyon
Mill Creek Ranger Sta
Allen Peak
Birch Mtn
Gaging Sta
Fallsvale Sch
Oak Glen Ranger Sta
BM 4846
SAN BERNARDINO
NATIONAL FOREST
Canyon
Oak Glen Sch
Wilson
Powerhouse
Potato

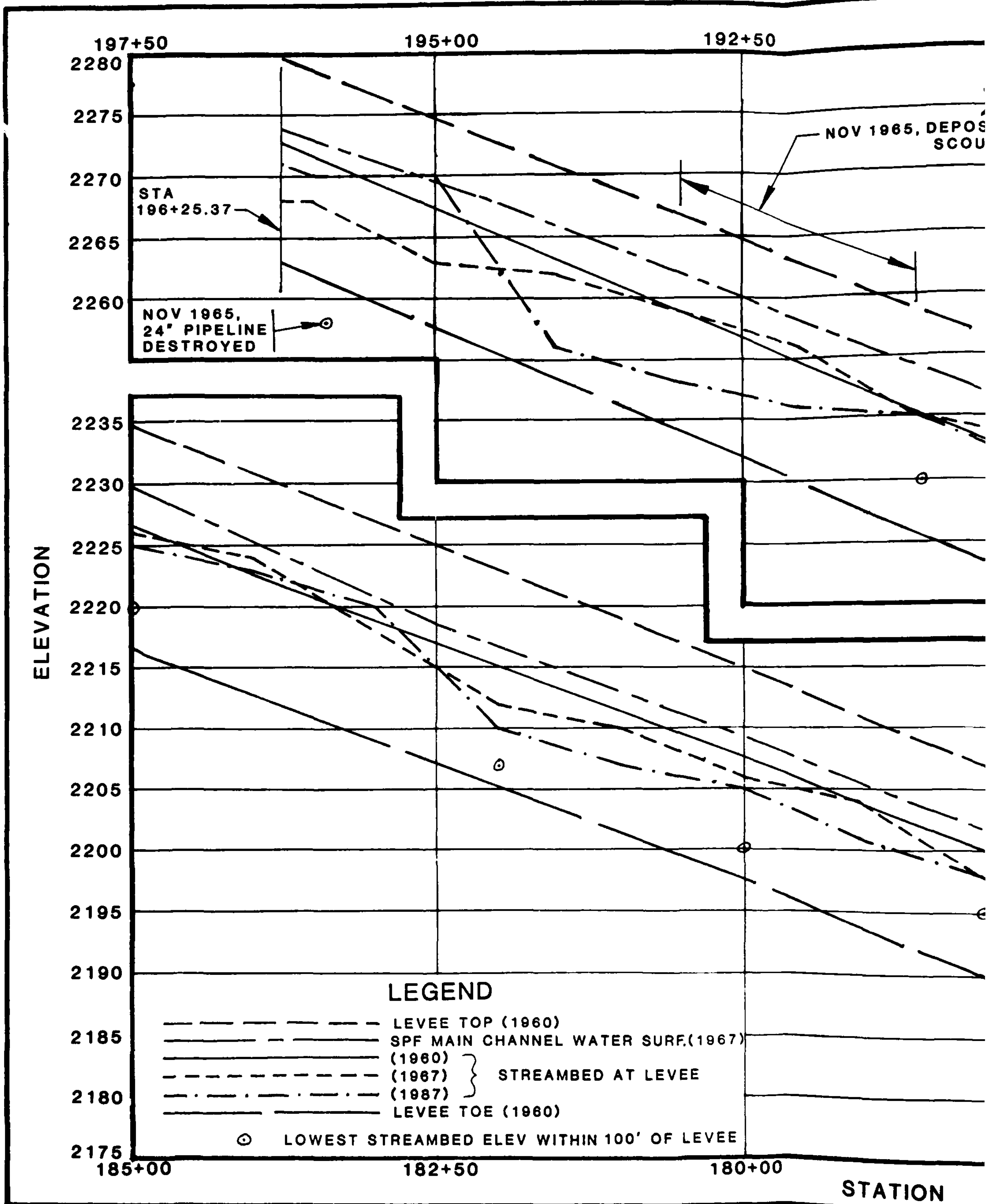


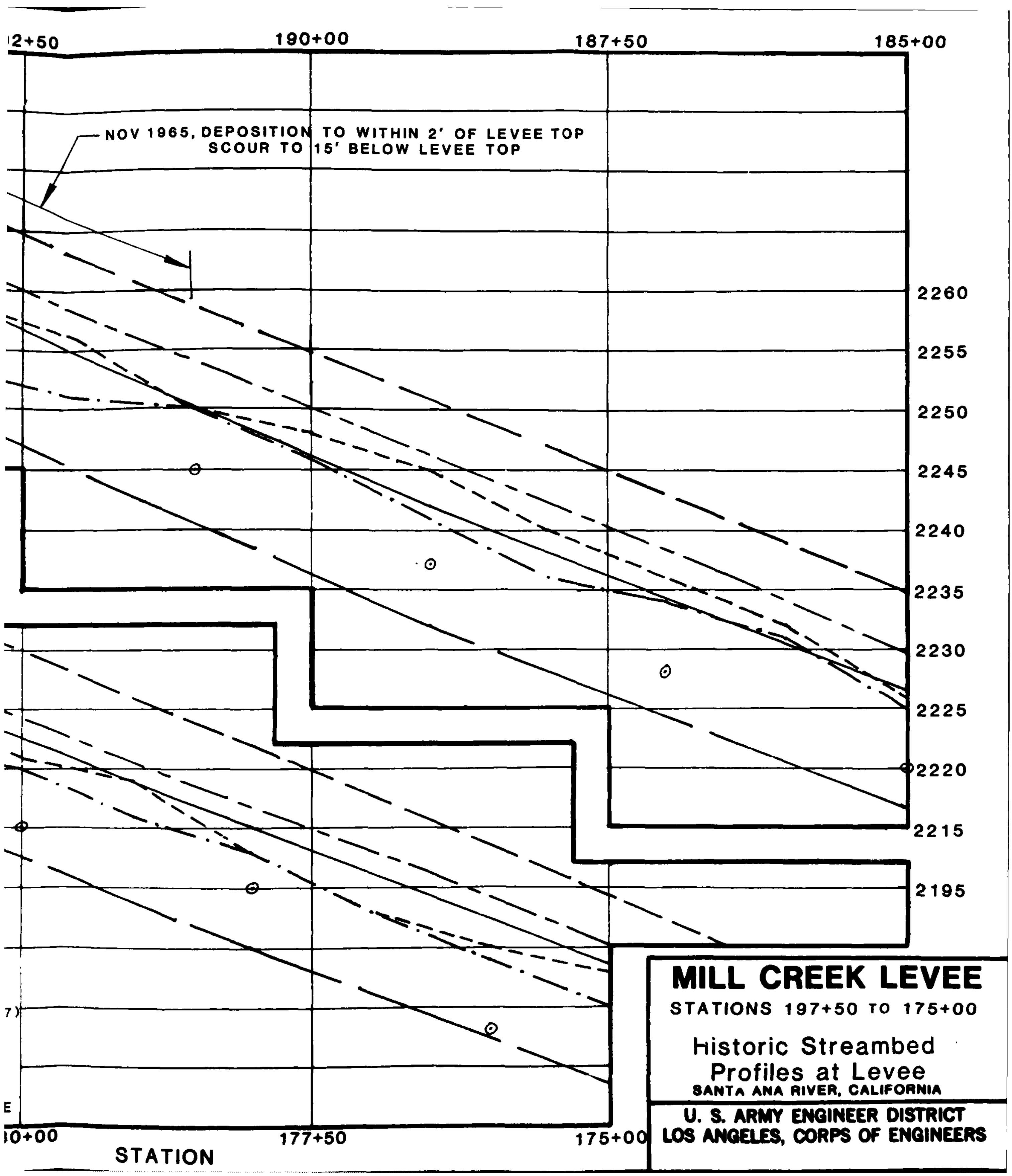
SANTA ANA RIVER MAINSTEM CALIFORNIA,
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK
DRAINAGE BASIN

US ARMY CORPS OF ENGINEERS
LOS ANGELES DISTRICT

U. S. ARMY ENGINEER DISTRICT





MILL CREEK LEVEE

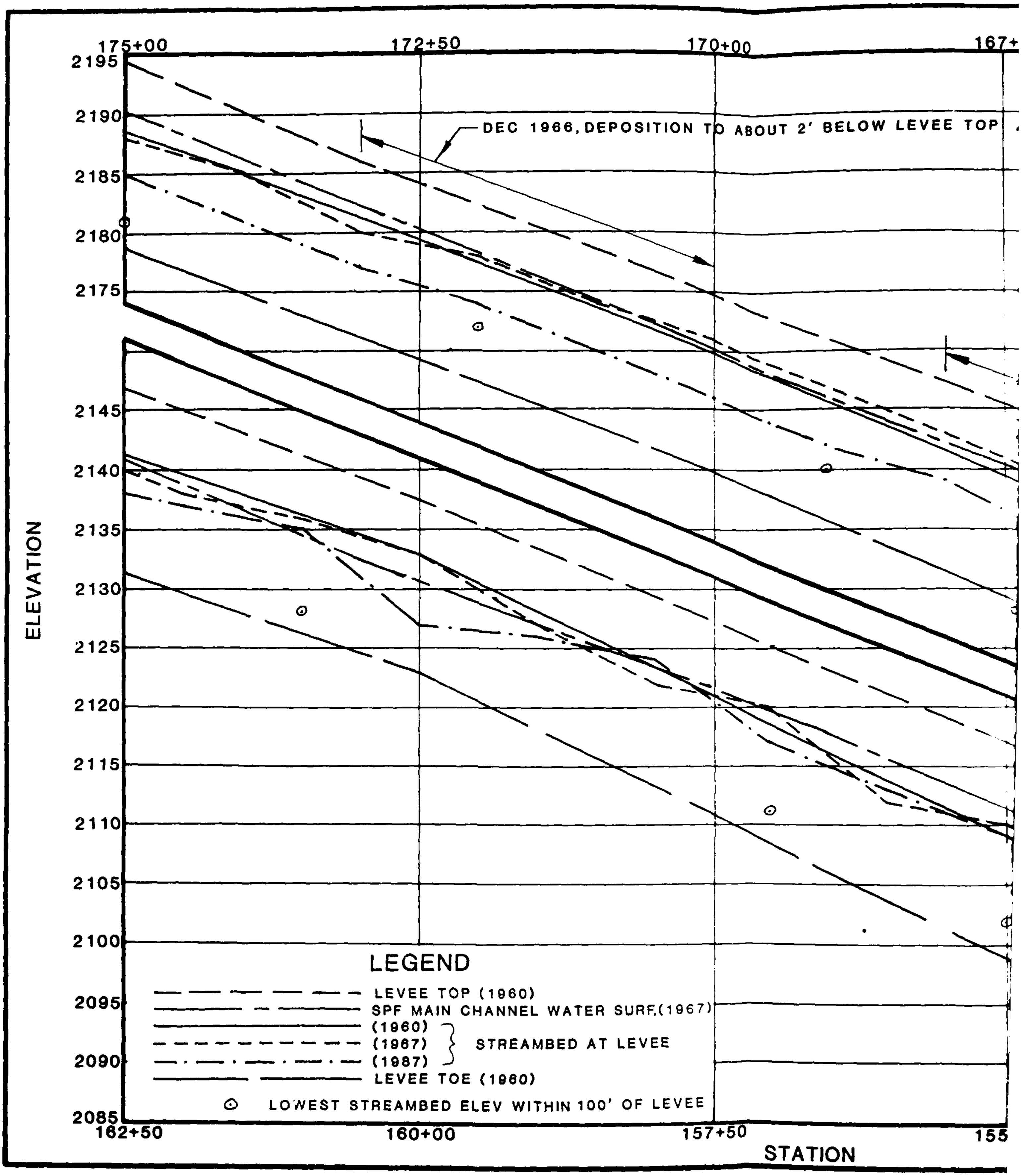
STATIONS 197+50 TO 175+00

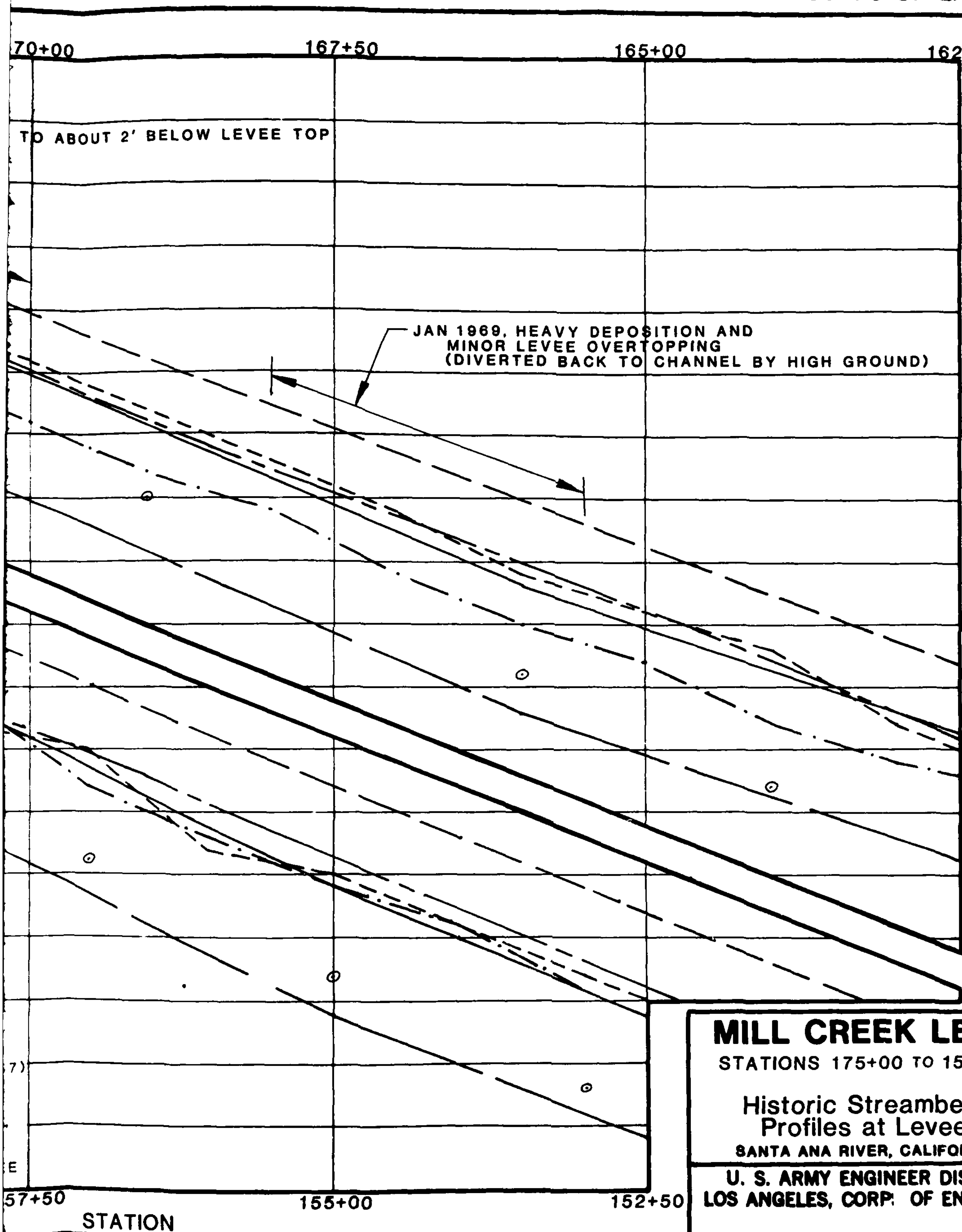
Historic Streambed Profiles at Levee

SANTA ANA RIVER, CALIFORNIA

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

U. S. ARMY ENGINEER DISTRICT





MILL CREEK LEVEE

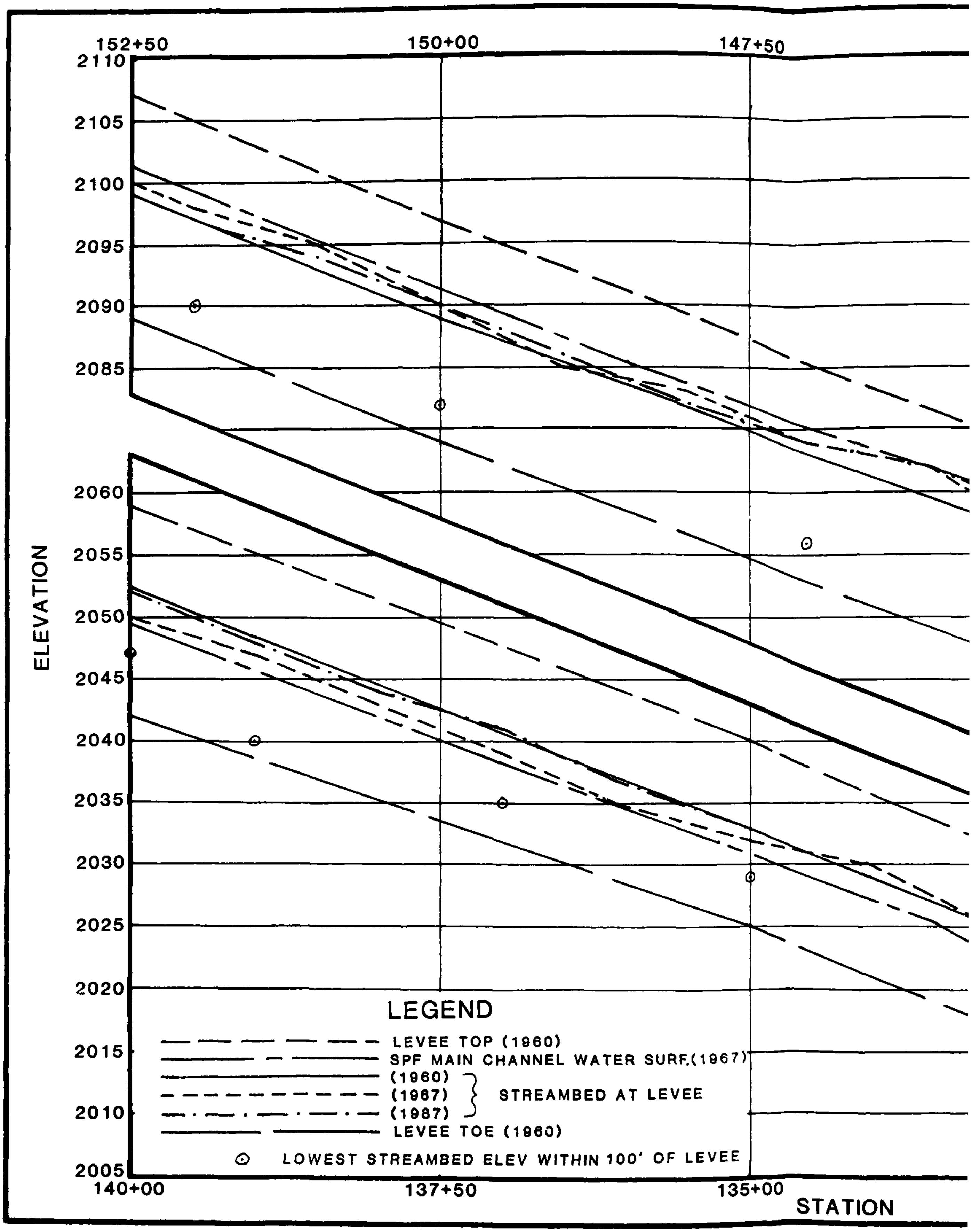
STATIONS 175+00 TO 152+50

Historic Streambed Profiles at Levee

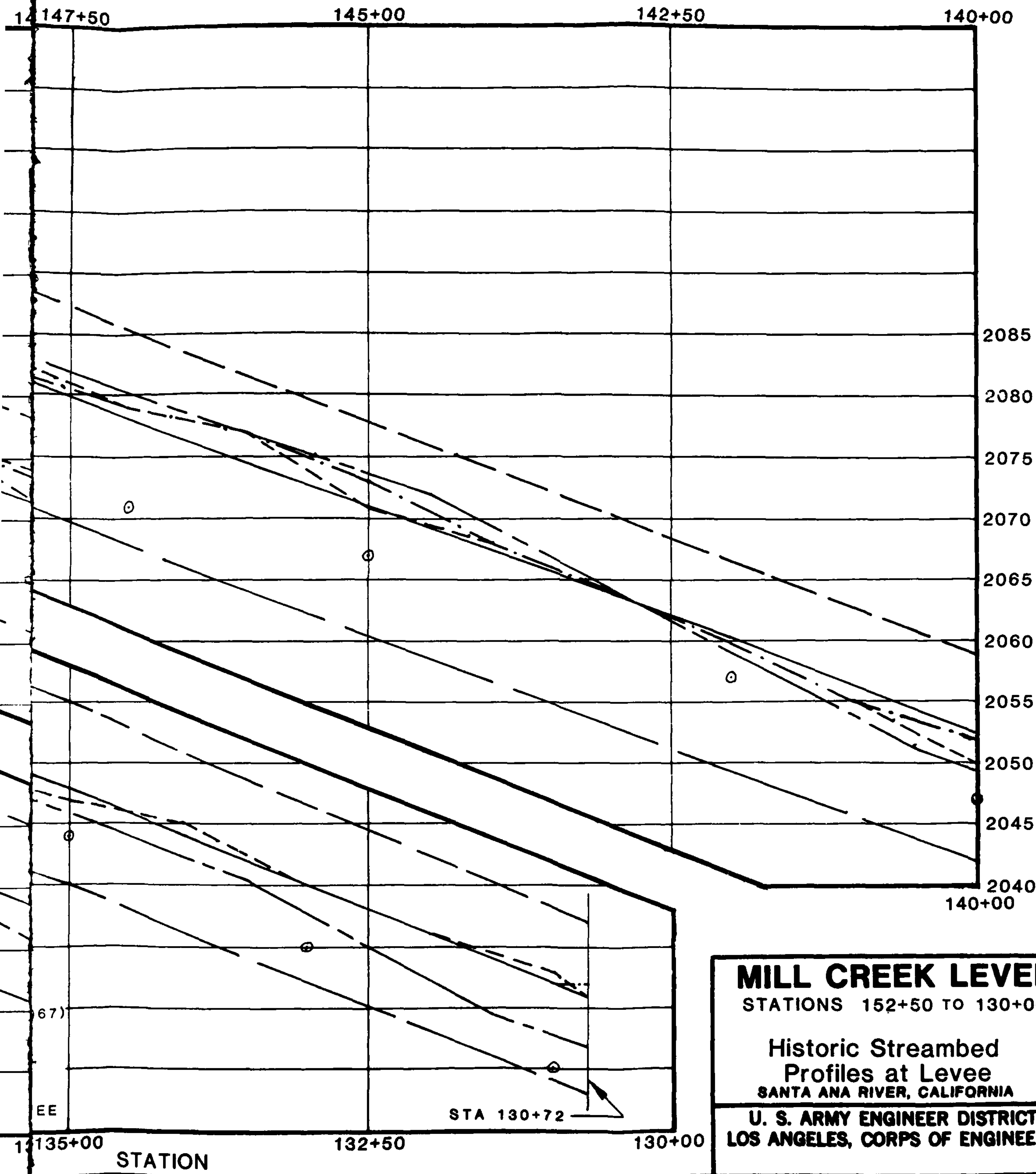
SANTA ANA RIVER, CALIFORNIA

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

U. S. ARMY ENGINEER DISTRICT



CORPS OF ENGINEERS



MILL CREEK LEVEE

STATIONS 152+50 TO 130+00

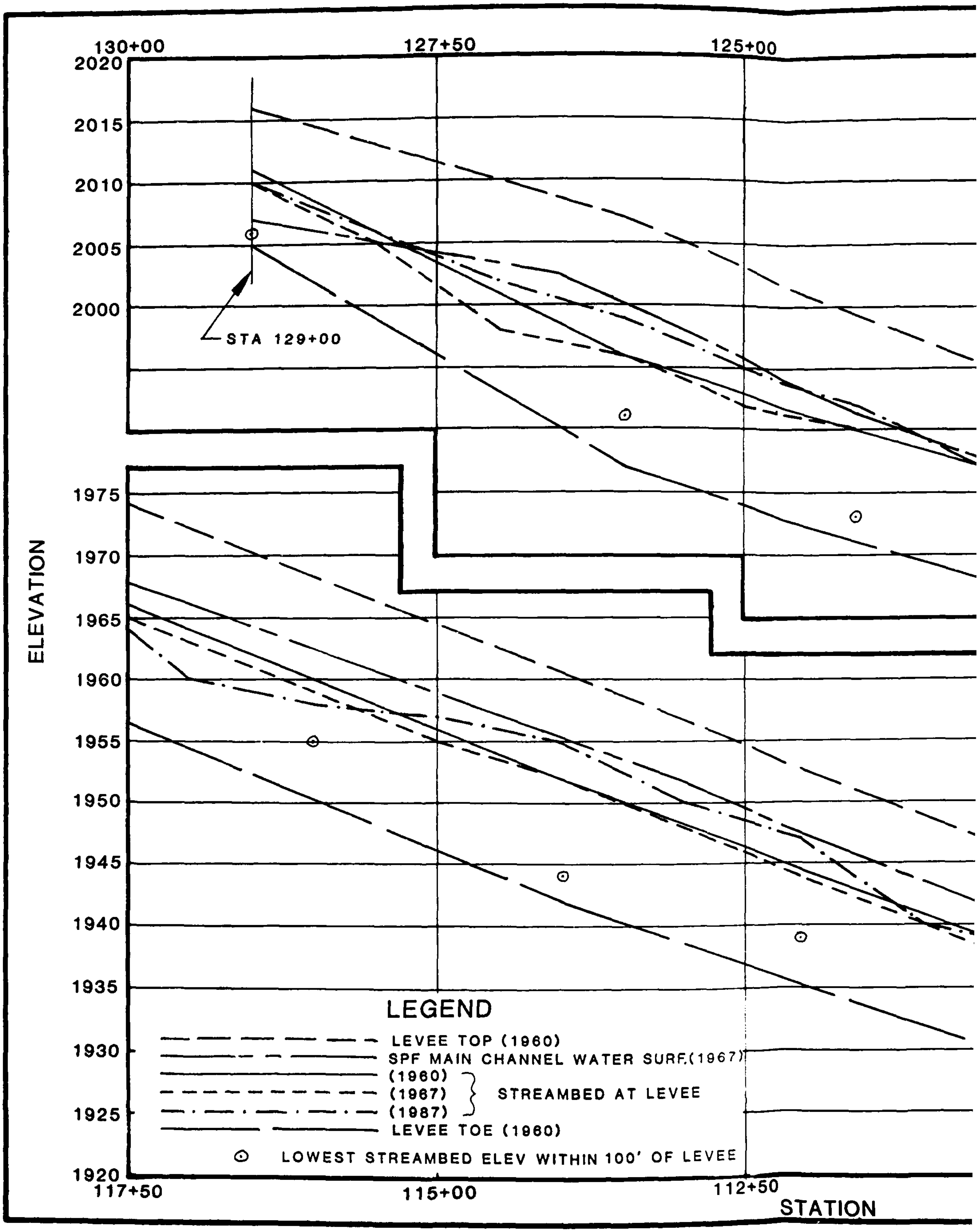
Historic Streambed Profiles at Levee

SANTA ANA RIVER, CALIFORNIA

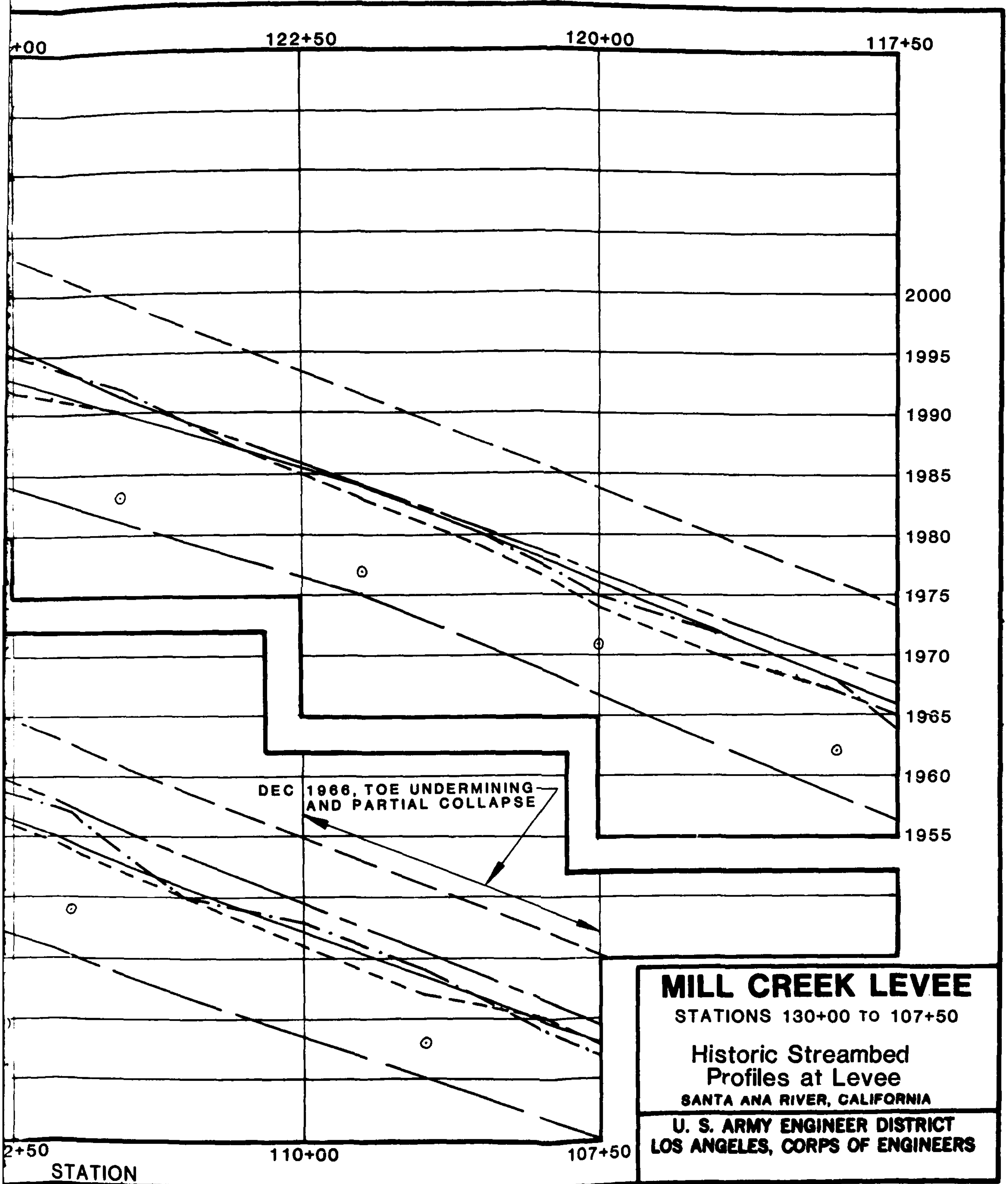
U. S. ARMY ENGINEER DISTRICT LOS ANGELES, CORPS OF ENGINEERS

PLATE 23

U. S. ARMY ENGINEER DISTRICT



CORPS OF ENGINEERS



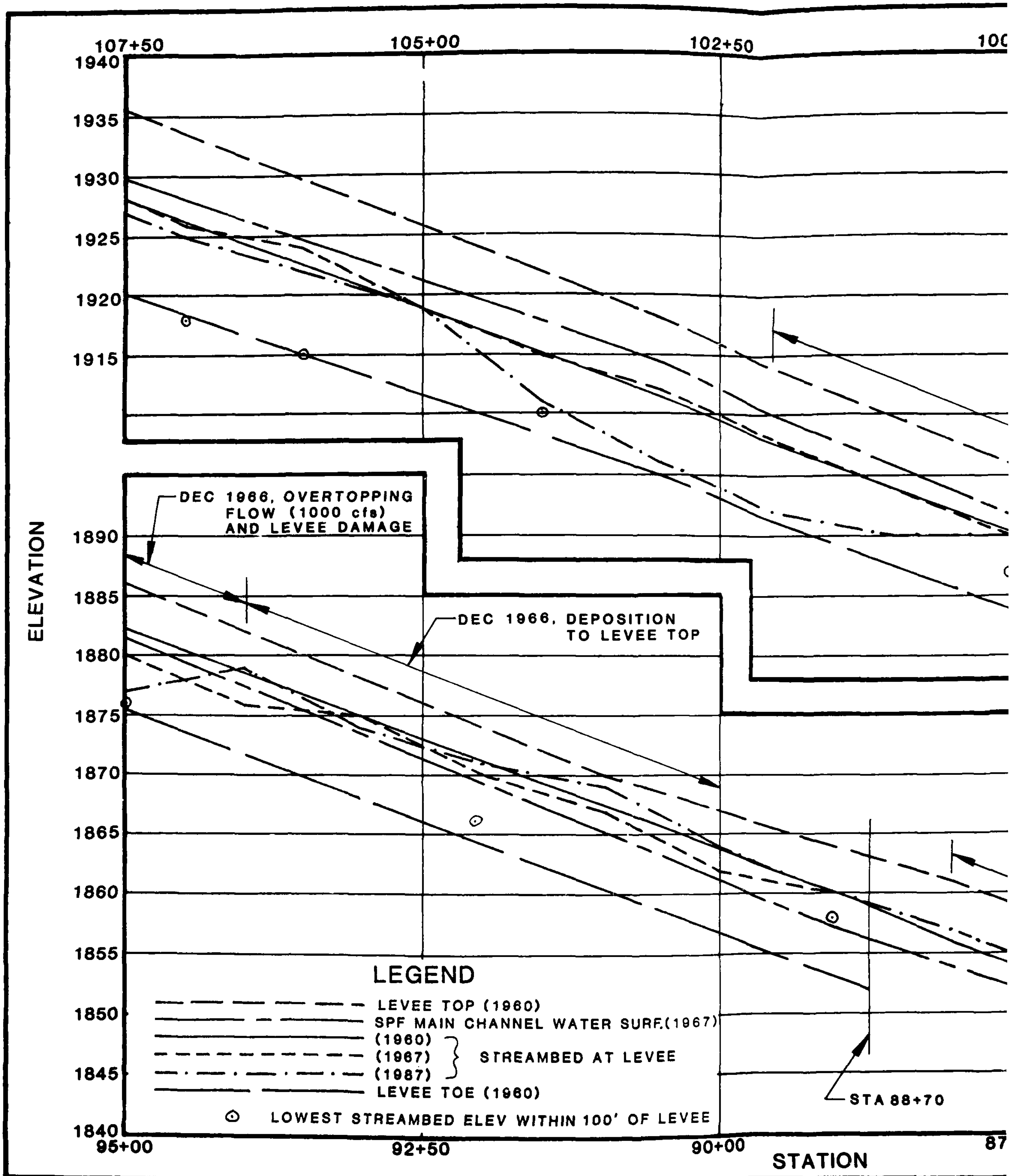
MILL CREEK LEVEE
STATIONS 130+00 TO 107+50

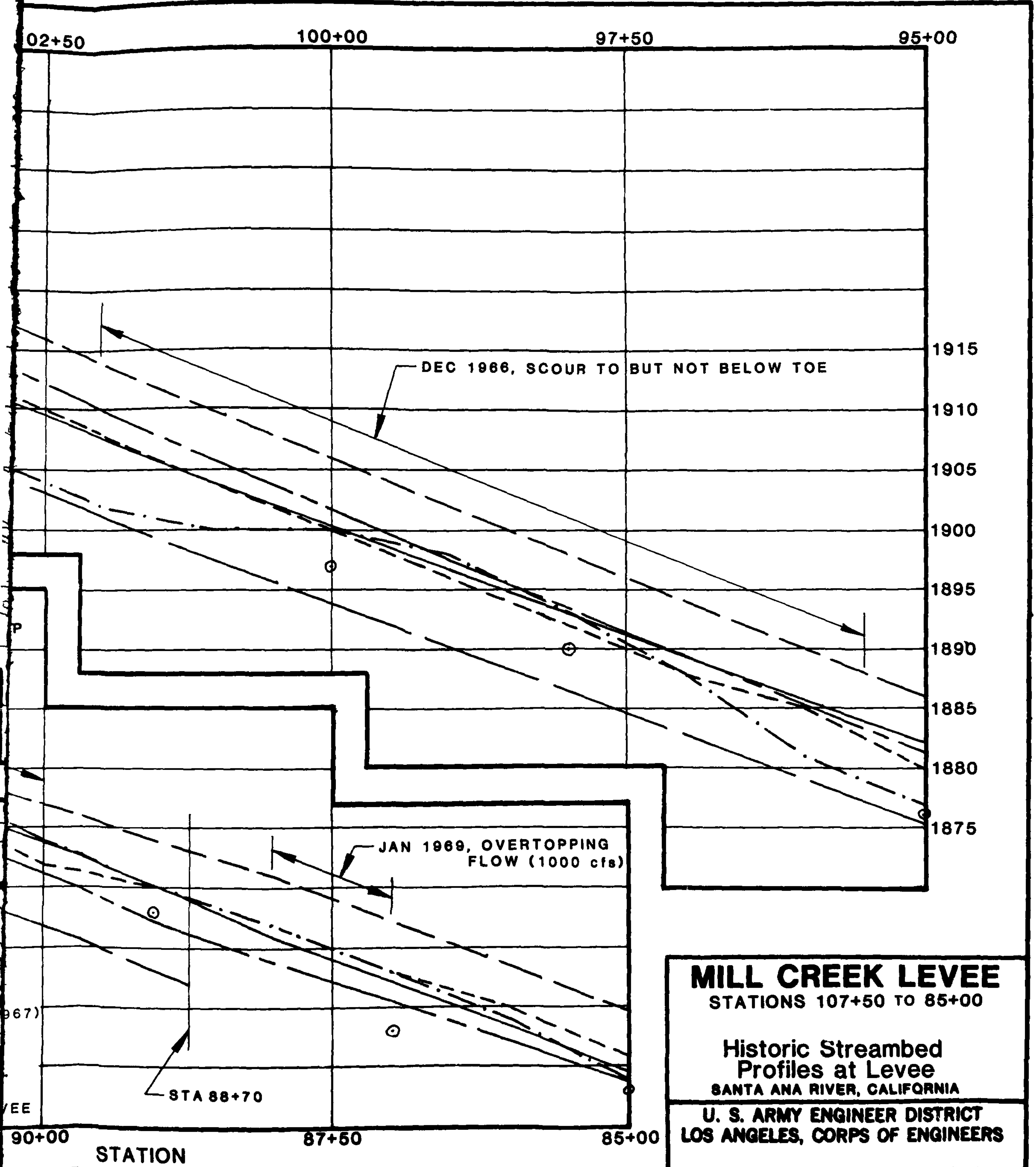
Historic Streambed Profiles at Levee

SANTA ANA RIVER, CALIFORNIA

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

U. S. ARMY ENGINEER DISTRICT





MILL CREEK LEVEE

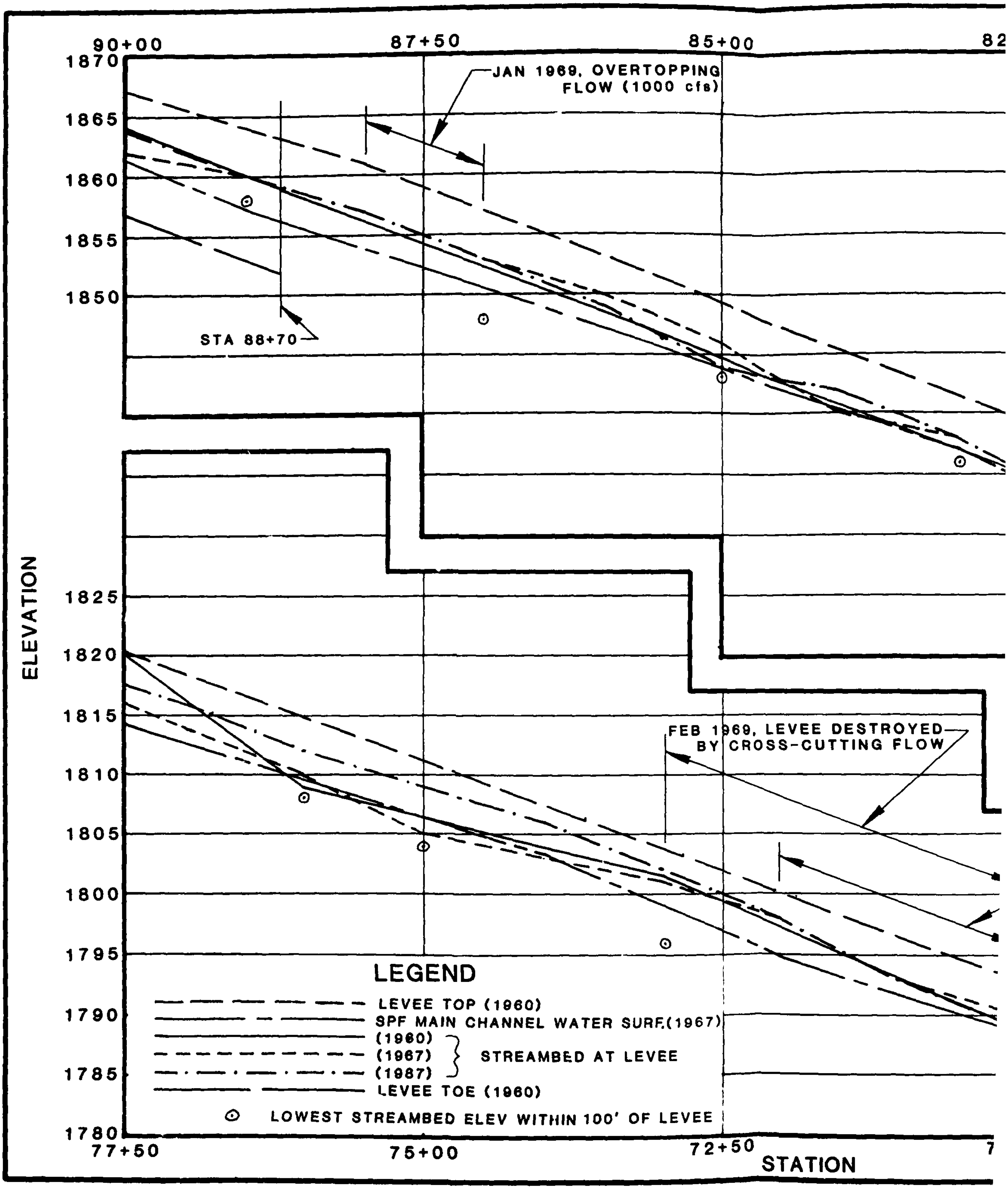
STATIONS 107+50 TO 85+00

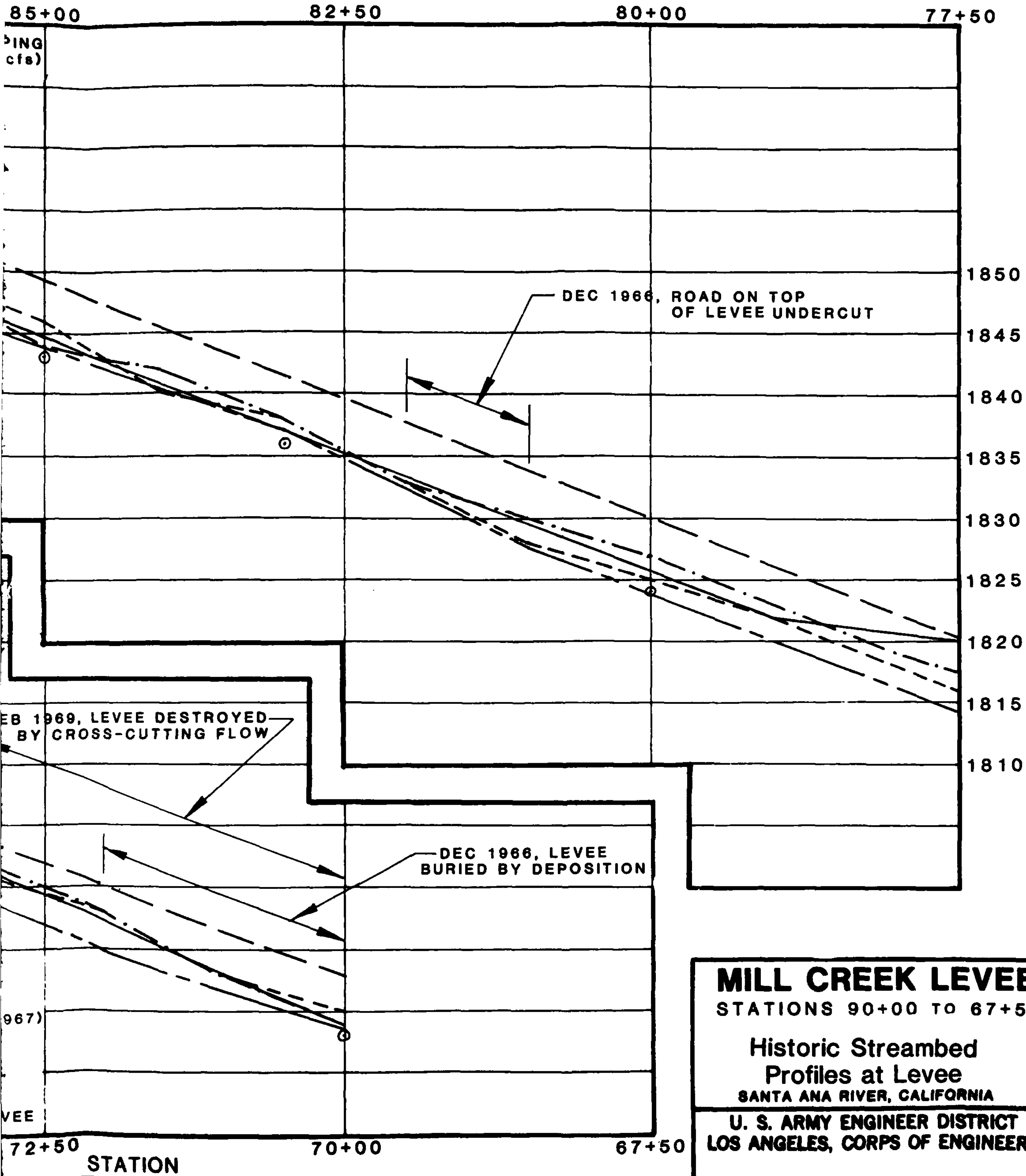
Historic Streambed Profiles at Levee

SANTA ANA RIVER, CALIFORNIA

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

U. S. ARMY ENGINEER DISTRICT





MILL CREEK LEVEE

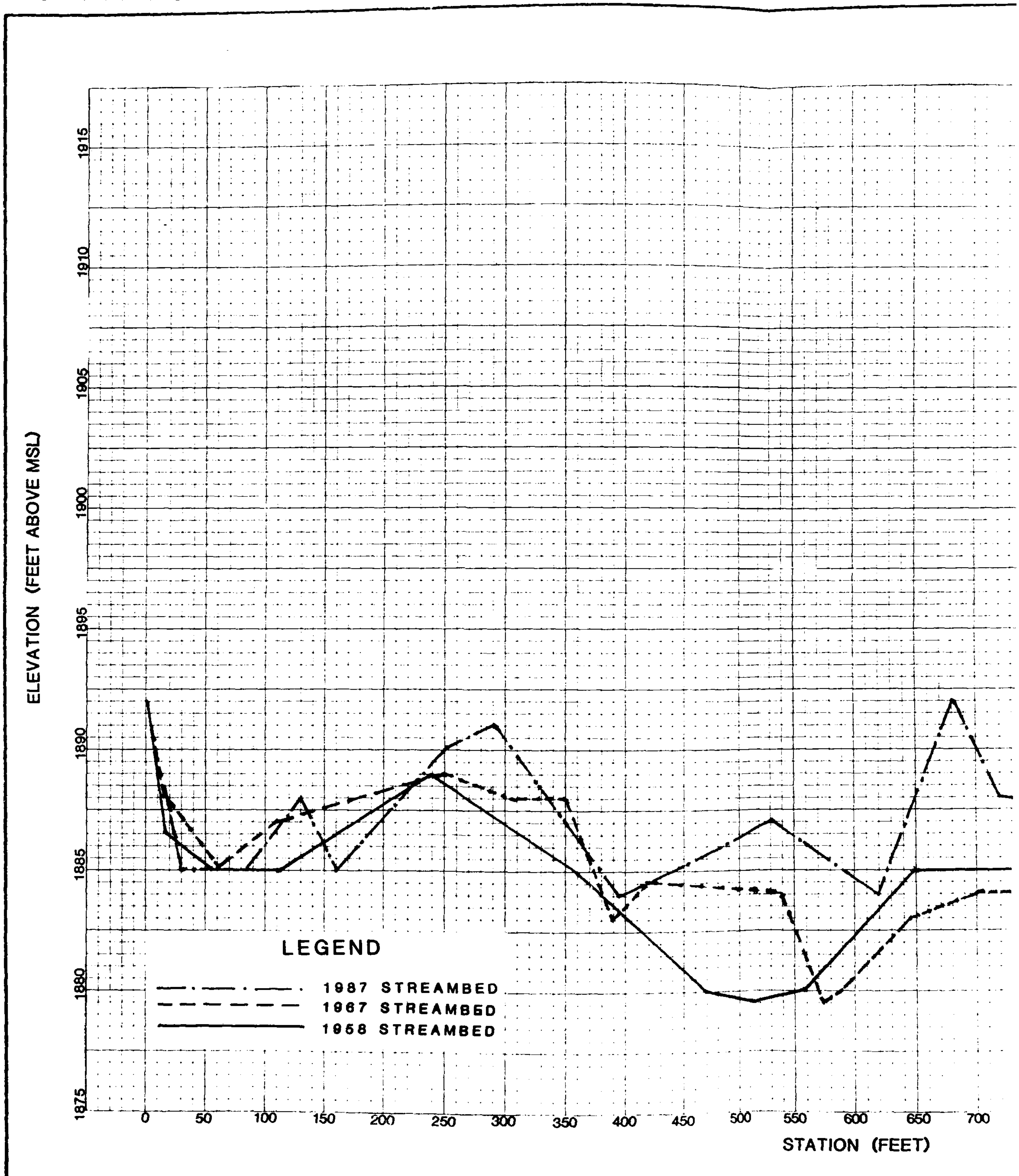
STATIONS 90+00 TO 67+50

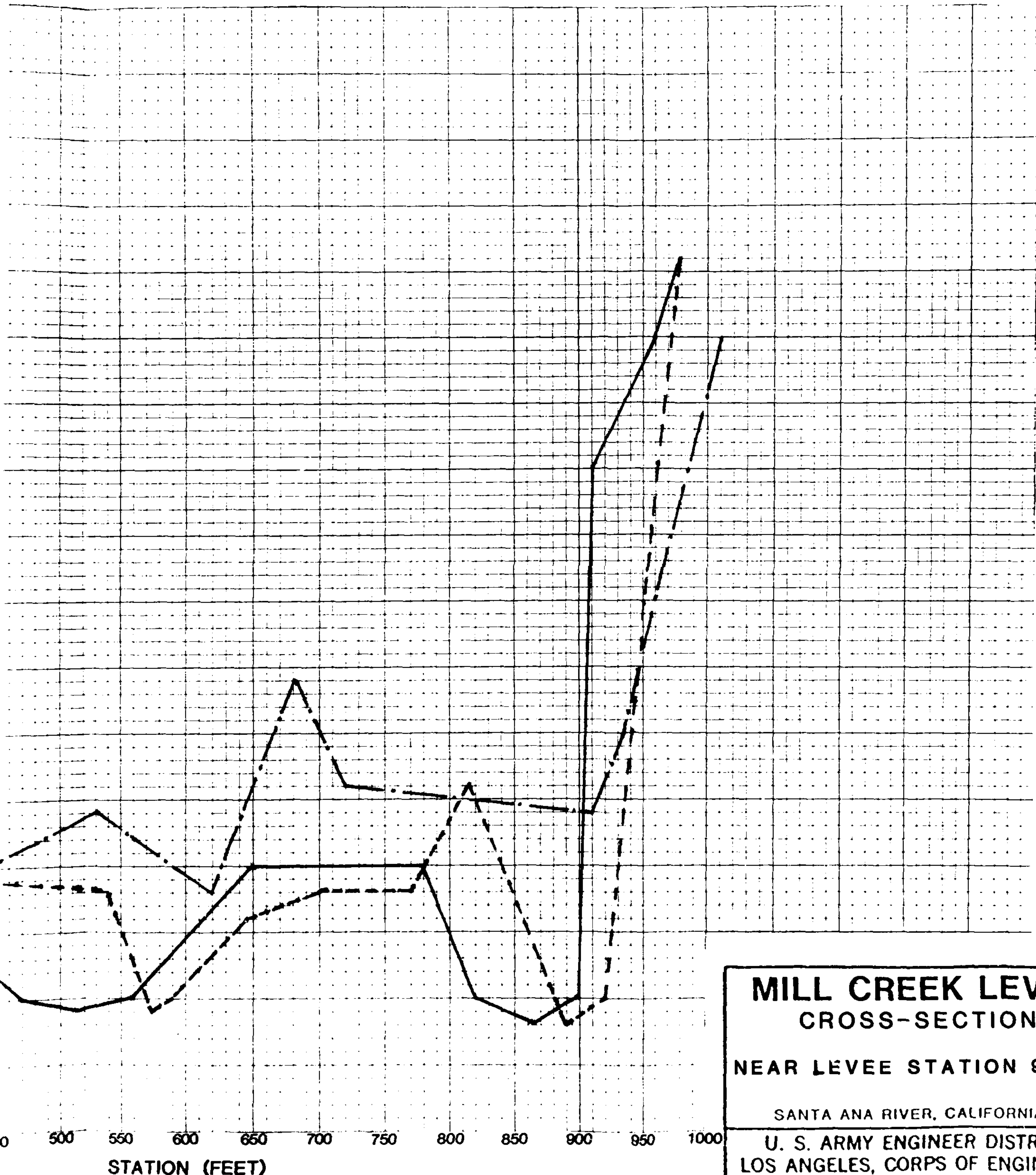
Historic Streambed Profiles at Levee

SANTA ANA RIVER, CALIFORNIA

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS

U. S. ARMY ENGINEER DISTRICT



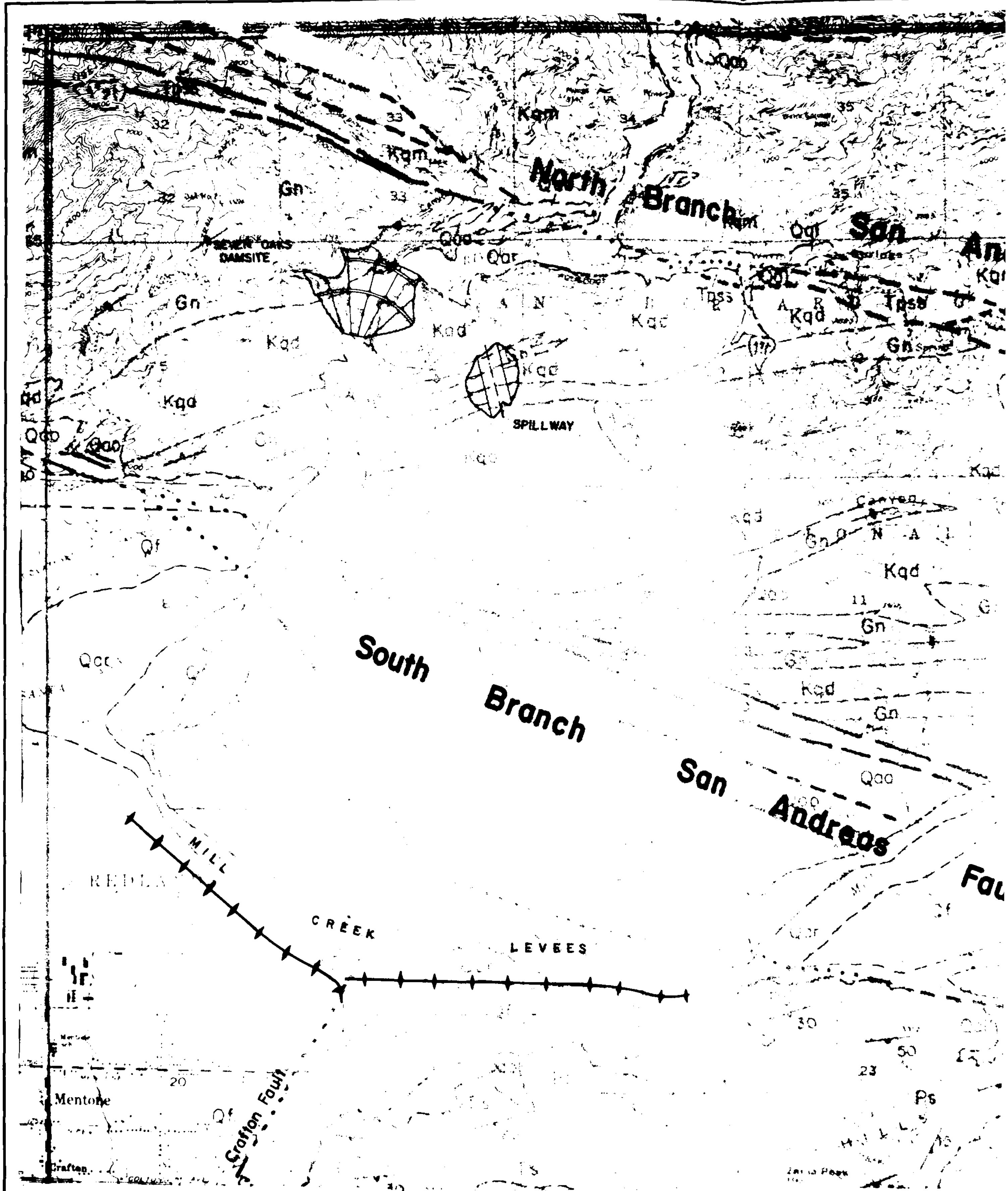


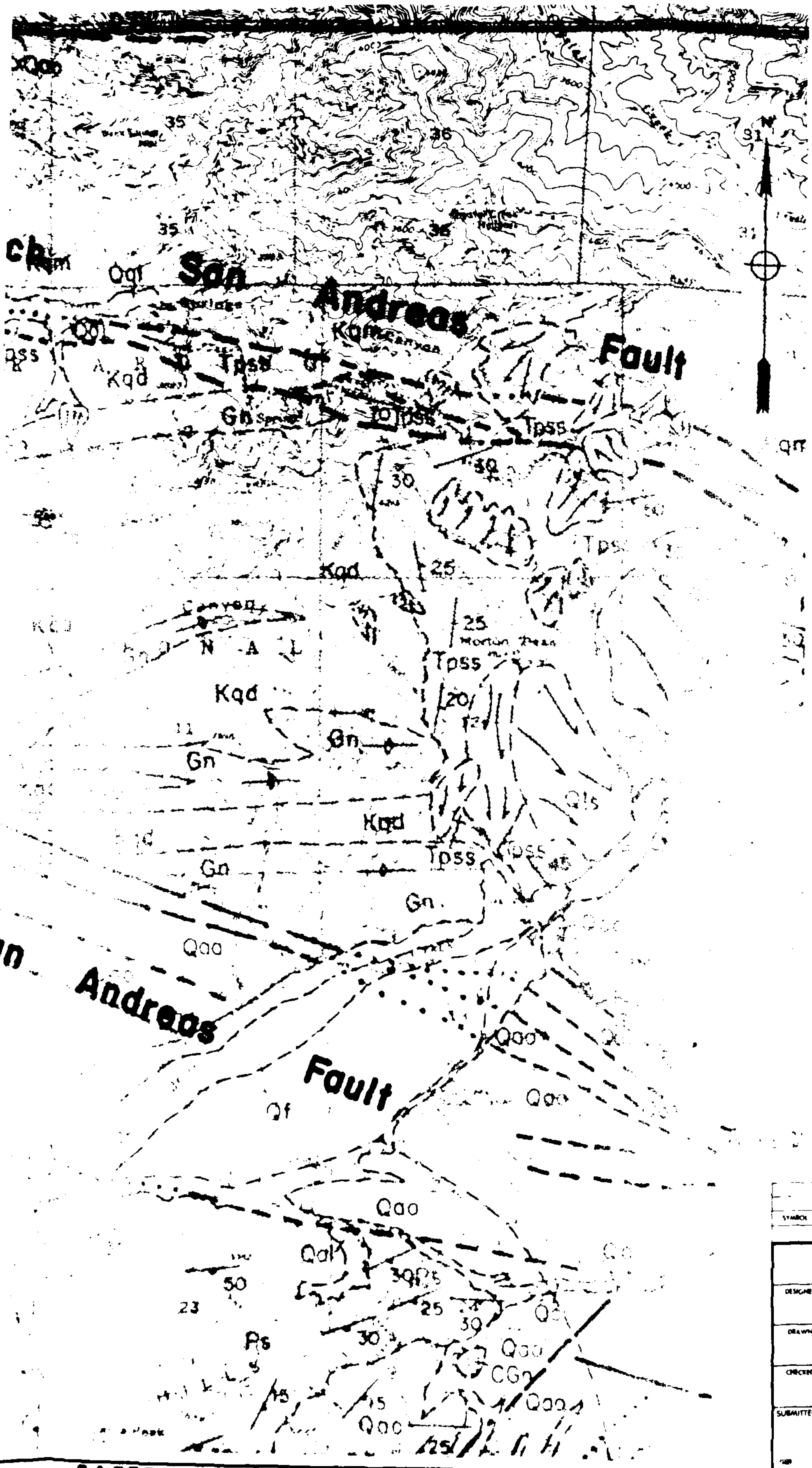
MILL CREEK LEVEE
CROSS-SECTION

NEAR LEVEE STATION 96+00

SANTA ANA RIVER, CALIFORNIA

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES, CORPS OF ENGINEERS


North Branch
San An
SEVEN OAKS DAMSITE
SPILLWAY
South Branch San Andreas Fau
MILL CREEK LEVEES
Crafton Fault
Mentone
Crafton
Canyon
Gn
Kqd
Kgm
Qao
Qal
Qf
Tpss
Ps



LEGEND

Qar	Active river channel alluvium
Qf	Alluvial fan deposits
Qal	Younger alluvium
Qls	Landslide deposits
Qao	Older alluvium
Tpss	Potato Sandstone
Kqm	Cretaceous quartz monzonite
Ps	Pelona schist
Gn	Gneiss and schist
	Contact; approximately located
	Fault; dashed where approximate; dotted where concealed
70	Strike and dip of bedding
	Strike of vertical bedding
75	Strike and dip of foliation
	Strike of vertical foliation

NOTE

Base map and geology is from: Geologic Hazards in Southwestern San Bernardino County, California, CDMG, Special Report 113.

SCALE 1000 0 1000 2000 3000 4000 FEET

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY

DRAWN BY

CHECKED BY

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE

REGIONAL GEOLOGY

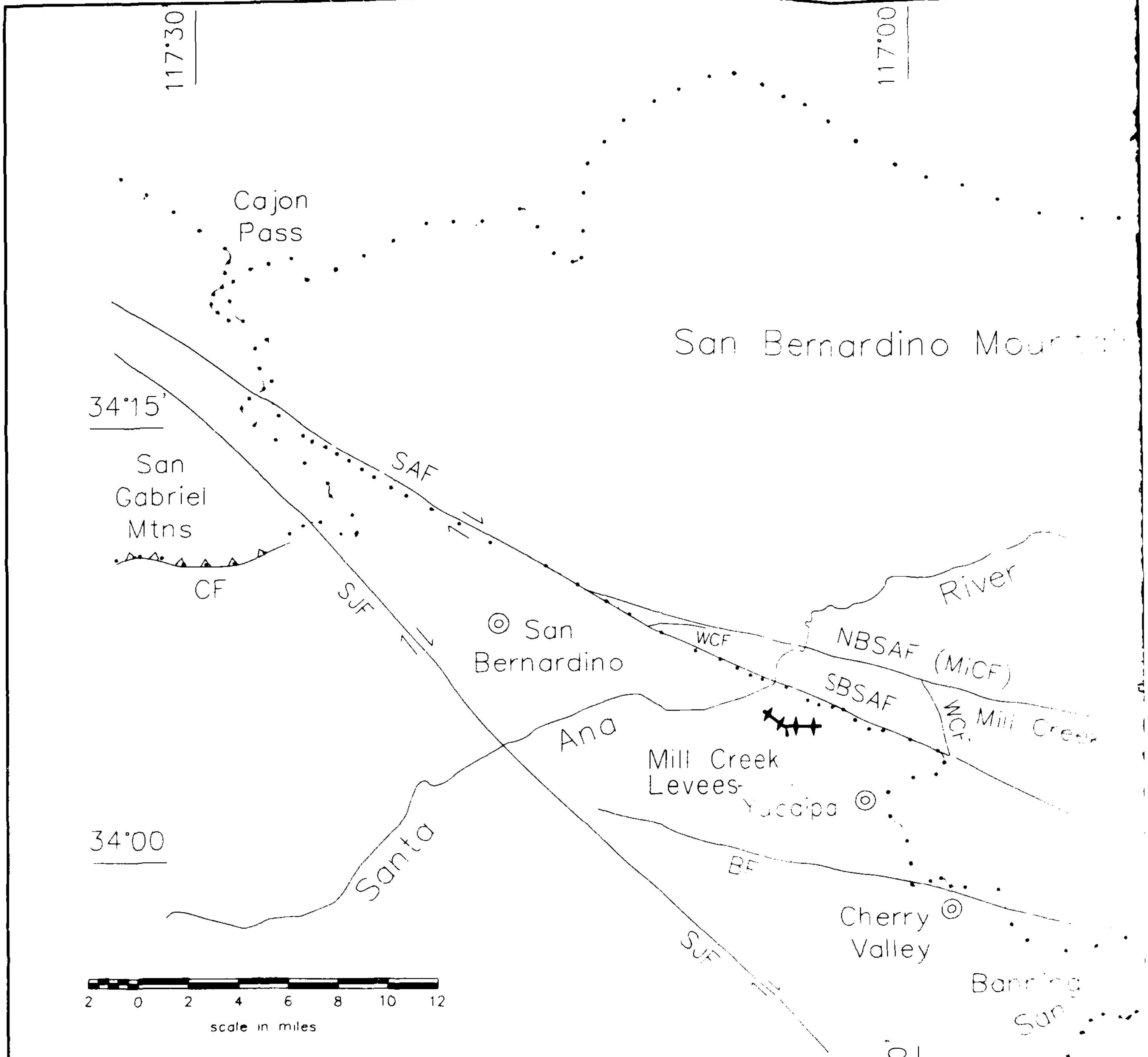
SUBMITTED BY

DATE APPROVED

SPEC NO. DACW09-

DISTRICT FILE NO.

SHEET 1 OF 1



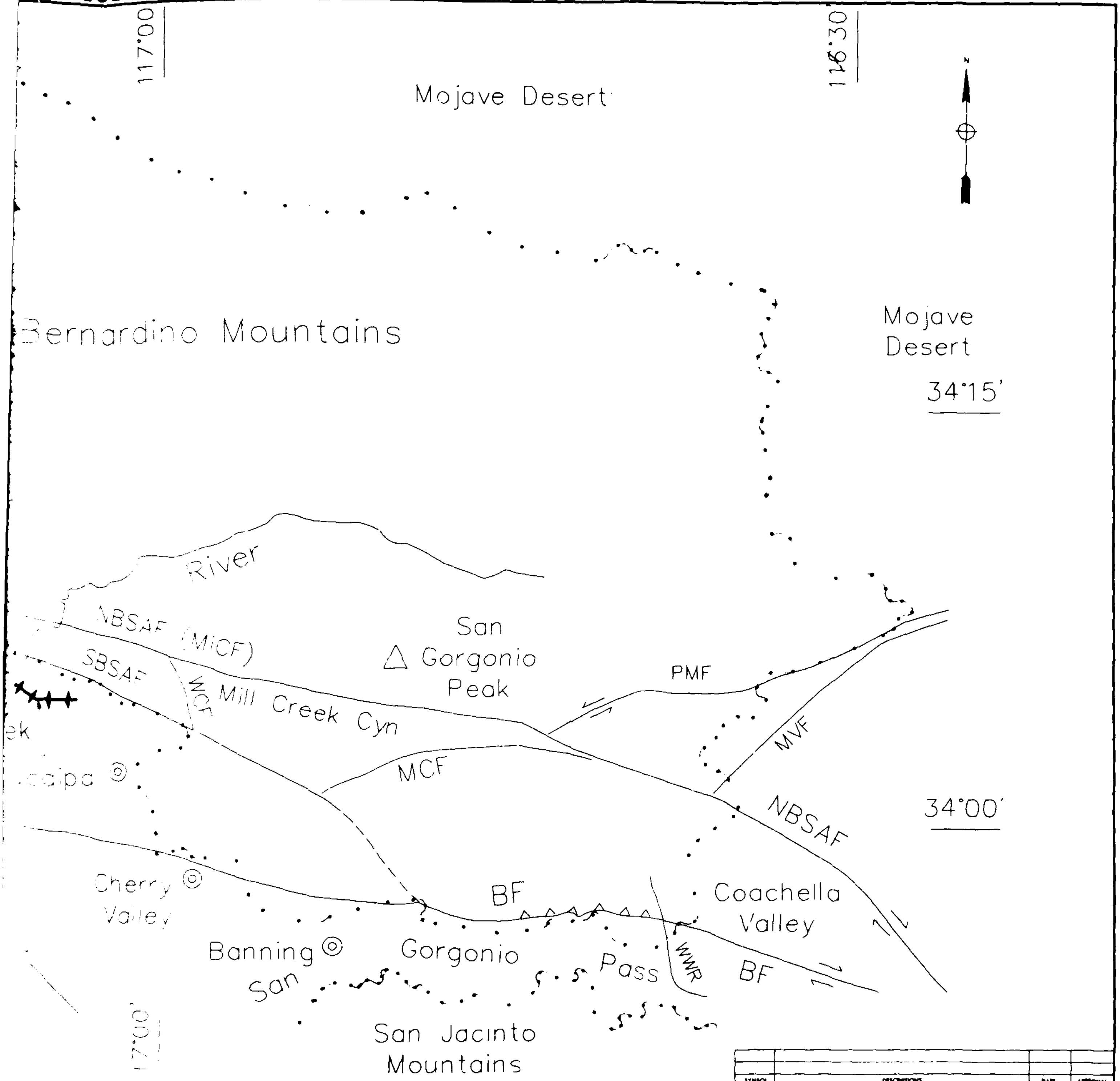
LEGEND:

- Thrust fault, barbs on the upthrown side
- Uncertainty in fault trace location
- Limts of mountain range

ABBREVIATIONS:

BF	Banning Fault	MVF	Morongo Valley Fault	SBSAF	South Branc
CF	Cucamonga Fault	NBSAF	North Branch, San Andreas Fault	SJF	San Jacinto
MCF	Mission Creek Fault	PMF	Pinto Mountain Fault	WCF	Wilson Creek
MiCF	Mill Creek Fault	SAF	San Andreas Fault	WWR	Whitewater R

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING



drecs Fault

SBSAF South Branch, San Andreas Fault
SJF San Jacinto Fault
WCF Wilson Creek Fault
WWR Whitewater River

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

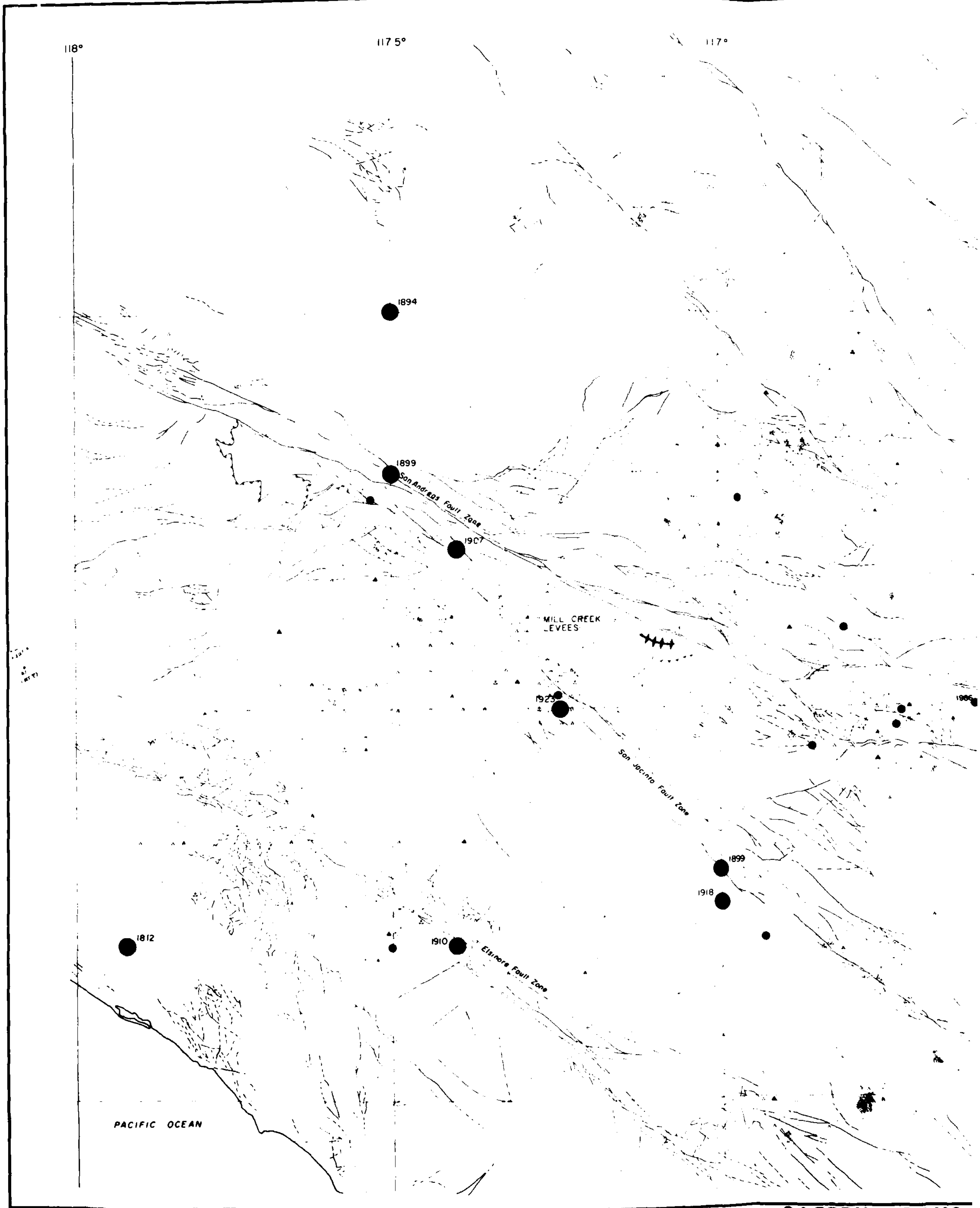
DESIGNED BY:
DRAWN BY:
CHECKED BY:

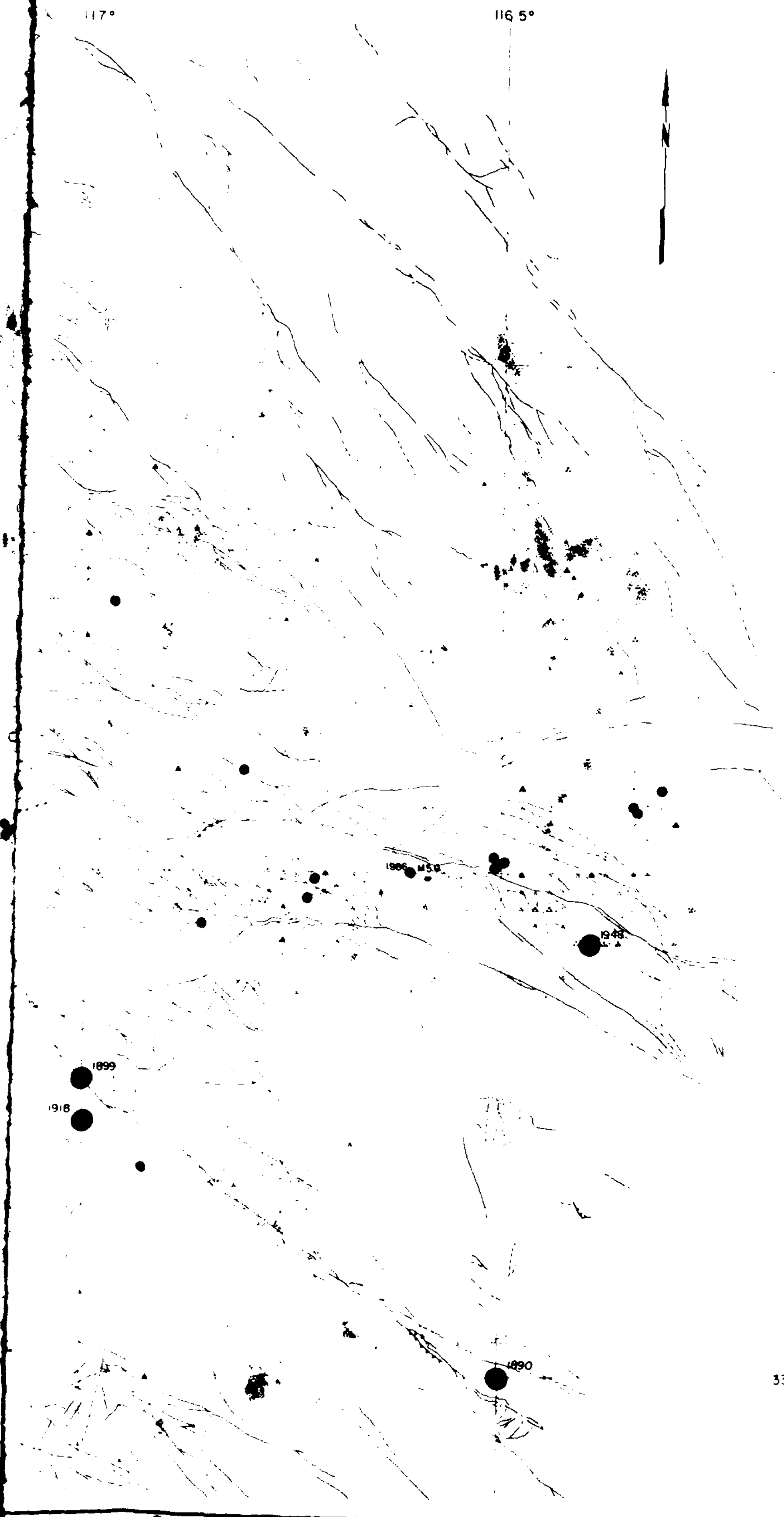
SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE
REGIONAL TECTONIC MAP

SUBMITTED BY: DATE APPROVED: SPEC NO. DACW09-____ B-____ SHEET 1 OF 1
DISTRICT FILE NO.

ENVIRONMENTAL ENHANCEMENT THRU ENGINEERING





LEGEND

- ▲ EARTHQUAKE EPICENTER - MAGNITUDE 2.0-3.9
- △ MAGNITUDE 4.0-4.9
- ● MAGNITUDE 5.0-5.9
- 1948 ● MAGNITUDE 6+ EARTHQUAKE IN 1948
- FAULT - dashed where approximately located, dotted where concealed
- THRUST FAULT

GENERAL NOTES

1. All earthquakes with magnitudes 2.0 or greater from 1932 to 1982 within a 50-mile radius are plotted
2. Base fault map compiled from the CDMG Geologic Map of California
3. The 1986 magnitude 5.9 North Palm Springs Earthquake is plotted due to its recency, magnitude and proximity
4. Historic earthquakes with magnitudes 6.0 or greater are shown with year of occurrence

SCALE 5 0 5 10 15 20 MILES

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

DESIGNED BY:
DRAWN BY:
CHECKED BY:

SANTA ANA RIVER MAINSTEM CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

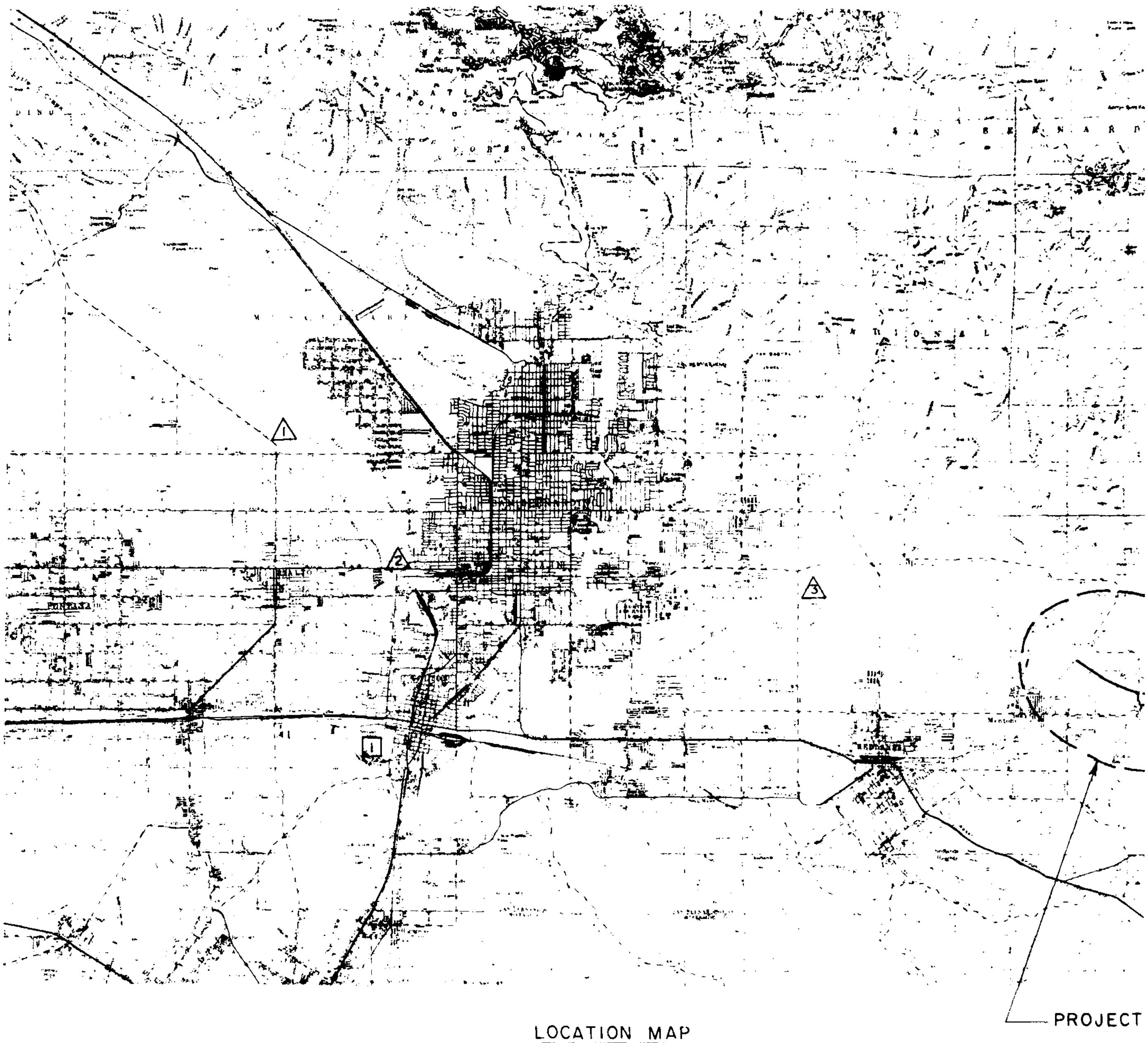
MILL CREEK LEVEE

FAULT AND EARTHQUAKE EPICENTER MAP

SUBMITTED BY: DATE APPROVED: SPEC NO. DACW09-____-B-____ SHEET 1 OF 1
DISTRICT FILE NO.

VALUE ENGINEERING

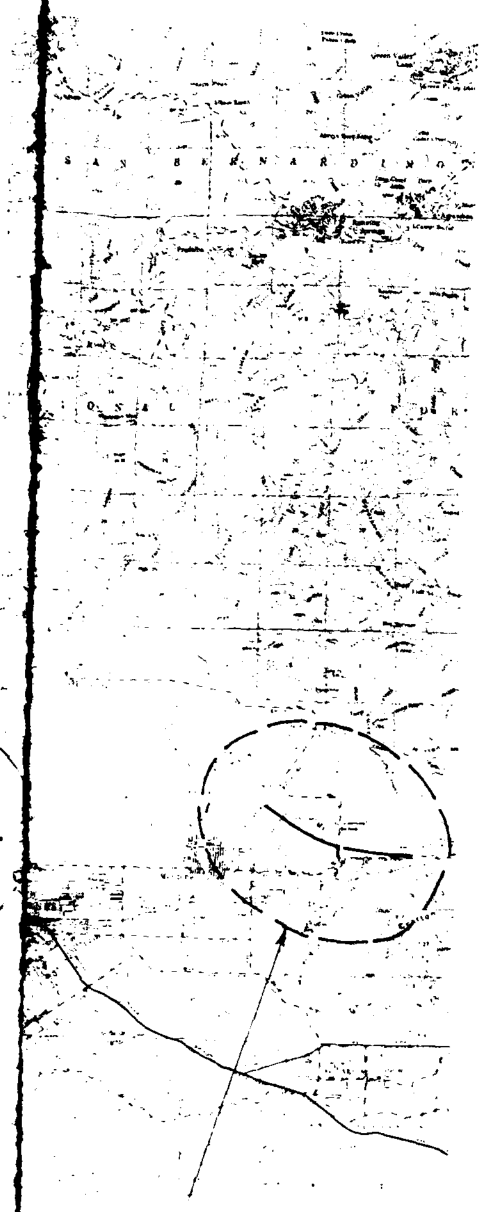
ENVIRONMENTAL
ENHANCEMENT
THRU ENGINEERING



LOCATION MAP
SCALE 1:62500

SCALE MILES
SCALE 3000 0 3000 6000 9000 12000 FEET
SCALE KILOMETERS

SAFETY PAY



AGGREGATE SOURCES EXAMINED

LYTLE CREEK SOURCES
(SEE LOCATION MAP)

1. OWL ROCK COMPANY
2. 4TH STREET CRUSHER

SANTA ANA RIVER
(SEE LOCATION MAP)

3. C.L. PHARRIS

SAN GORGONIO RIVER
(SEE VICINITY MAP)

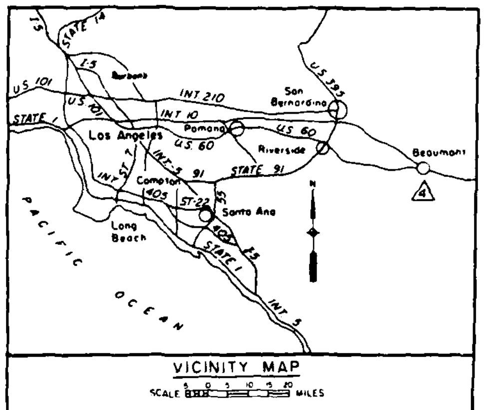
4. BEAUMONT CONCRETE COMPANY

CEMENT SOURCES

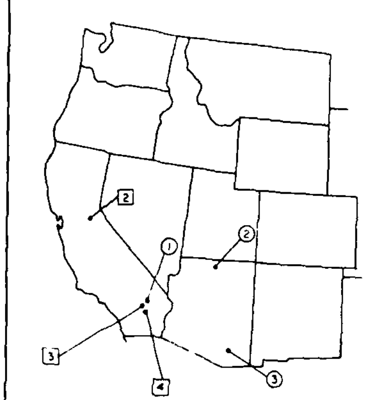
1. CALIFORNIA PORTLAND CEMENT COMPANY (CALMAT) COLTON, CALIFORNIA
2. CALAVERAS CEMENT COMPANY SAN ANDREAS, CALIFORNIA
3. CALMAT MOJAVE, CALIFORNIA
4. RIVERSIDE PORTLAND CEMENT COMPANY ORO GRANDE, CALIFORNIA

POZZOLAN SOURCES

1. WESTERN ASH CO. MOJAVE PLANT MOJAVE, CALIFORNIA
2. WESTERN ASH CO. NAVAJO PLANT PAGE, ARIZONA
3. WESTERN ASH CO. APACHE PLANT COCHISE, ARIZONA



VICINITY MAP



GENERAL MAP

NO SCALE

SYMBOL	DESCRIPTIONS	DATE	APPROVAL

REVISIONS

U. S. ARMY ENGINEER DISTRICT
LOS ANGELES
CORPS OF ENGINEERS

SANTA ANA RIVER MAINSTEM, CALIFORNIA
PHASE II GENERAL DESIGN MEMORANDUM

MILL CREEK LEVEE

SOURCES OF AGGREGATES, CEMENTS, AND POZZOLANS

DESIGNED BY
DRAWN BY
CHECKED BY
SUBMITTED BY
DATE APPROVED
SPEC NO DACW09-
DISTRICT FILE NO
SHEET 1 OF 1

PLATE 31